STATIONARY ENGINE, BY WOODBURY, BOOTH & PRYOR, ROCHESTER, N. Y.

HAND-BOOK

FOR

STEAM ENGINEERS

AND

OWNERS OF

STEAM ENGINES,

BEING

A PRACTICAL GUIDE TO THE SELECTION AND CARE OF STEAM MACHINERY.

BY

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PREFACE.

The preparation of this little book has been undertaken at the suggestion of several persons who have presented their views to the writer from the various standpoints of the manufacturer, dealer, and user of steam machinery, in which it was made to appear that a small and convenient hand-book was greatly needed, one which would present to those who had no practical knowledge of the steam engine a summary of its principles and action; the treatment to be simple and within the easy comprehension of any who should have occasion to read it; that it shall also contain some hints in regard to the selection of steam machinery, and advice as to its care and management when in use.

It was with some hesitancy and many misgivings that the book was undertaken, because it seemed doubtful whether so large a subject could be successfully presented by so small a book; and be of any practical value to the persons for whom it was intended.

In the presentation of this subject so as to advise the purchaser what to buy, and then instruct another how to use it, was beset with more difficulties than was anticipated at the beginning; I have endeavored to be faithful to both parties and the reader will have to decide for himself as to whether the advice given is the best or not. The sharp limitations as to space prevented illustrated and descriptive articles, which would have added much to the appearance and attractiveness of the book.

The manufacture and use of steam engines for small powers has within the limits of a single generation grown into gigantic proportions. When it is known that more than half, and perhaps three-fourths of these engines are to be managed by men who have had no previous experience in the management of steam machinery, the educational value of a reliable book of ref-

erence can hardly be over-estimated. It is useless to say that such persons should not be entrusted with the care and management of steam boilers, it is nevertheless a fact, and a fact likely to continue for years to come, from the very nature of the case. Recognizing this, several manufacturers in urging the preparation of this book, said: "We want a little book that we can afford to give each purchaser of an engine and boiler, one which will give him hints and suggestions in regard to their proper use."

This demand comes also from the farmers, a class of men who must have engines whether they know how to use them or not. These persons do not want an elaborate treatise on the steam engine, but simply a little hand-book which shall furnish a certain needed information and nothing else.

The reason why proportions and details of construction are omitted is because the persons for whom this little book is prepared are not manufacturers nor dealers, but simply users of steam machinery. The engine comes into their hands a complete working machine; the end and aim of this book is merely to present the leading features of engines and boilers now in the market, and to assist the reader in making a suitable selection, and then to give some practical hints in regard to the proper care and management.

WILLIAM M. BARR.

Indianapolis, Ind., May, 1880.

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CHAPTER I.

FUEL AND COMBUSTION.

The engine, boilers, and furnace being erected, the proper starting point which suggests itself for this little hand book is fuel.

We have in this country wood, peat, lignite, bituminous, semi-bituminous and anthracite coals available as fuel. Perhaps the most abundant and lowest in price of the fuels named is bituminous coal. It is found in nearly every state in the union and is especially plentiful and cheap in the Western and some of the Southern States.

East of the Allegheny mountains anthracite coal is to be had in abundance and is a very desirable fuel. It is very nearly pure carbon, yields an intense heat, and burns without smoke. It is the chief fuel of Pennsylvania, Maryland, New Jersey, New York, Connecticut, Massachusetts and Rhode Island.

In other localities the forests still furnish an abundance of cheap fuel, and the furnaces are arranged with reference to its use.

Combustion, as generally understood by steam engineers means the rapid combination of the carbon and hydrogen of the fuel with the oxygen of the atmosphere, for the purpose of generating heat.

The active agents in the generation of heat from fuel are mainly the union of the carbon and hydrogen in the fuel, with the oxygen of the atmosphere. How heat is produced by this combination is not certainly known, and has been largely speculated upon by specialists. Professor Tyndall says "all cases of combustion are to be ascribed to the collision of atoms which have been urged together by their mutual attractions." That is, the atoms of carbon and oxygen under certain conditions have such an affinity for

each other that they rush together with such violence that they produce heat and light by collision, just as a flint and steel produce light and heat by collision. This is the accepted theory, but why it is so, or how to account for it we do not know, but we do know something of the conditions necessary to combustion.

It is known that carbon and oxygen, or hydrogen and oxygen, will remain together as a mixture at ordinary temperatures almost any length of time without entering into that condition we call ignition and combustion. The ordinary coal gas used in our houses is a hydro-carbon gas, that is, a gas composed of hydrogen with carbon entering into its composition. If the cock to a burner be opened the gas will escape, but the only effect discovered will be a disagreeable smell; if however, a lighted match be introduced into this jet of escaping gas, ignition and combustion immediately follow. From this simple experiment we know that one of the conditions necessary to combustion is that the two gases, the one escaping from the gas burner, and the oxygen of the atmosphere, must be raised to a certain temperature. Nor is this all, this temperature must be continued or combustion will cease. This same principle applies to the furnace, or a stove, or any other place where combustion is to be effected; once ignition has taken place and combustion begun, it may be continued so long as the conditions are favorable for it.

The union of these gases, carbon and oxygen, and hydrogen and oxygen, occurs in certain fixed proportions. Carbon will unite with oxygen in the formation of two separate compounds known as carbonic oxide ($C O$) and carbonic acid ($C O_2$) as follows:

	Parts by weight.	
	Carbon.	Oxygen.
Carbonic Oxide ($C O$)	12	16
Carbonic Acid ($C O_2$)	12	32

The latter is the product of perfect, the former of imperfect combustion.

Hydrogen, when similarly burned, unites with oxygen in the proportion of one part of hydrogen to eight parts of oxygen, by weight, and forms water, ($H_2 O$).

The heating powers of carbon and hydrogen may be expressed thus:—

One pound of carbon such as pure charcoal or coke will liberate by combustion, say 14,500 heat units, if the product of combustion be carbonic acid gas, or—

One pound of carbon such as pure charcoal or coke will liberate by combustion, say 4,500 heat units, if the product of combustion be carbonic oxide gas.

It will be seen that there is a difference of 10,000 heat units in a total of 14,500 whether the carbon be burned to carbonic acid or carbonic oxide gas, and illustrates the difference between partial and complete combustion.

One pound of gaseous hydrogen similarly burned would yield, say 62,000 heat units; when the hydrogen is to be distilled from the coal in the furnace it is somewhat less as a certain amount of heat is required to liberate it from the fuel.

Practically, the question is a commercial rather than a theoretical one; the fuel which the immediate locality supplies is the one to be used; sometimes it is a question whether anthracite or bituminous coals shall have the preference when both are competing in the same market.

The construction of the furnace and other considerations will generally determine which is to be used. As a general practice the grates are placed lower in the furnace for bituminous than for anthracite coal, the latter being about 18 inches, the former 24 to 30 inches. When a boiler furnace is constructed for anthracite coal it is perhaps better to continue its use unless the difference in price is such that it will pay to take out the old front and put in a new one.

There is not much difference between the heating power of the best bituminous and anthracite coals when taken at equal weights.

Whether wood or coal shall be used as a fuel in generating steam will depend upon the relative cost and heating power of each. In order to determine this it will be necessary to know among other things what there is in each of the fuels offered from which heat may be generated; and then how much of these combustible elements are contained in each of the two.

In the analysis of wood we find the following substances, and in

average composition the figures given are near enough correct for our present purpose:

	Per cent.
Carbon	49.70
Hydrogen	6.06
Oxygen	41.30
Nitrogen	1.05
Ash (difference)	1.89
	100.00

Of the above only the carbon and hydrogen are combustible, that is, these two elements unite with oxygen and result in a disengagement of heat, the total quantity of which may easily be approximated in some such way as this:

One pound of pure carbon, such as charcoal or coke when perfectly burned, will raise the temperature of 14,500 pounds of water one degree Fahrenheit, from 39° to 40°. One pound of hydrogen when similarly burned will raise the temperature of 62,000 pounds of water in the same amount; thus it will be seen that the heating power of hydrogen is more than four times as much as carbon.

The next element in the table is oxygen; this is a supporter of combustion, and in order to get it into the fire we arrange openings in the grate bars for air to pass through, and thus allow the oxygen in the air to combine with the carbon or hydrogen in the fuel, and in this way heat is generated, as we usually express it. The presence of oxygen in any fuel to be burnad is a bad thing, because it lowers the heat producing power of the fuel and it does it in this way: When oxygen and hydrogen are present in the same fuel they unite to form water. Oxygen unites with one-eighth of its own weight of hydrogen to form water; thus ⅛ of 41.3 equals 5.16 per cent. of hydrogen rendered useless in the fuel because of the presence of oxygen in it at the same time.

For the theoretical heating power of the wood we take all the carbon 49.70 per cent. and only 0.90 per cent. of hydrogen (6.06—5.16=0.90.)

To get the heating power of one pound of wood we have. therefore,

	lbs.	Heat units.
Carbon	.497 x 14,500	=7,207
Hydrogen	.009 x 62,000	= 558
Total heat units in one pound of wood		7,765

This does not take into account the loss of heat occasioned by

the presence of 1.05 per cent. of nitrogen, which is not a supporter of combustion, but which is heated to the same temperature as the other gases in the fire.

It should be understood that the above total number of heat units in one pound of wood is for wood perfectly dry and specially prepared for analysis. Ordinary wood not dry, will contain about one-third of its weight of water. To evaporate this requires an expenditure of a portion of the heat already generated in the furnace. In addition to this there is more air admitted to the furnace than is needed for combustion by nearly one hundred per cent. This has the effect to lower the temperature; so that, taking into account the losses incident to burning wood, we have scarcely more than 5,500 heat units as actually available in the combustion of one pound of wood.

In estimating the heating power of bituminous coal, a proximate analysis is made to ascertain the amount of water present in the sample; this is done by evaporation; then, to ascertain what quantity of volatile combustible matter it contains; and lastly the quantity of coke. The latter also includes all the earthy matter known as ash. Excluding the ash from the coke gives the fixed carbon. An average analysis of bituminous coal will not vary much from the following:

	Per cent.
Fixed Carbon	55
Volatile combustible matter	30
Moisture	10
Incombustible matter	5
	100

Proceeding in the same manner in which we ascertain the theoretical heating power of the wood, we have then in one pound of coal:

	lbs.		Heat units.		
Carbon	.55	x	14,500 =		7,975
Volatile combustible matter	.30	x	20,115 =	6,035	
Less the moisture	.10	x	3,600 =	360	
					5,675
Total heat units in one pound of coal					13,650

In the above calculation the moisture has been deducted and the heat units of the volatile combustible matter given as ascer-

tained by calorimeter tests; we then have 13,650—7,766=4,885 more heat units in one pound of bituminous coal than in the wood.

If we take into account the various losses incident to burning this pound of coal, excluding the moisture, as this loss is already taken into account, we shall have not far from 13,000 effective units of heat. Then

	Heat units.
One pound of coal equals	13,000
One pound of wood equals	5,500
Difference in favor of coal	6,500

To put it in another shape, one pound of coal is equal to 2.36 pounds of wood.

When good bituminous coal is used under a boiler with chimney draft, the combustion being complete and no great excess of air admitted to the furnace, it ought to evaporote ten pounds of water per pound of coal, good wood will evaporate about five pounds. There is not much difference in the heating power of the several kinds of wood when equally dry and taken pound for pound. If we take 2240 pounds per ton, then:

One ton in weight equals	1.2 cords	White Pine.
" " "	.97 "	Spruce.
" " "	.66 "	South'n Pine.
" " "	.77 "	Maple (hard)
" " "	.68 "	Red Oak.
" " "	.54 "	Hickory.

It is customary in evaporative tests to fix the heating power of good dry wood at 0.4, that of good coal. Assuming this, we have then:

One cord White Pine equals	747	pounds of coal.
" Spruce "	930	"
" Southern Pine "	1,350	"
" Maple (hard) "	1,150	"
" Red Oak "	1,300	"
" Hickory "	1,640	"

To fix a commercial value on coal and wood based on what has already been given, and taking $1.00 as the basis of calculation as the value of a ton of coal, we shall have:

$0.33 per cord of	White Pine.
0.41 "	Spruce.
0.41 "	Southern Pine.
0.51 "	Hard Maple.
0.58 "	Red Oak.
0.75 "	Hickory.

The use of the above table is too obvious to need much of an explanation; if good coal is worth $4.75 per ton. the relative price for hard maple would be $.75x51=$2.42 per cord, or $4.75x60=$2.85 per cord for southern pine, and in this manner for any other wood given in the table.

Whatever kind of fuel may be selected for regular use, its nature will have to be studied and the fire regulated accordingly. Some kinds of coal will not stand urging as much as others, on account of its forming a clinker which is not only difficult to remove from the grates, but acts as a hindrance to a free and perfect admission of air to the burning fuel. Coal of this kind should be spread over as large a grate area as possible, that the combustion be slow. Coals which burn to a red ash are more likely to yield a clinker in an intense fire than coals burning to a light brown or white ash.

CHAP. II.

HEAT AND STEAM.

The steam engine is a machine for the conversion of heat into power in motion. The heat is generated by the combustion of fuel; the transmission is accomplished through the agency of steam; the power is made available and brought under control by means of the engine.

The effect of heat upon water is to vaporize it, if there be intensity enough, the heat will under proper conditions cause water to boil; the vapor produced by boiling is called steam, and steam under pressure is a product which is the end and aim of that portion of the steam engine known as the boiler and furnace.

The steam engine then is to be considered as a form of heat engine; of which the furnace, boiler, and the engine itself are to be regarded as separate portions of the same mechanism.

The conditions demanded upon economic grounds to secure the highest efficiency in the steam engine are:

1. A proper construction of the furnace so as to secure the perfect combustion of fuel.
2. The heat generated in the furnace must be transferred to the water in the boiler without loss.
3. The circulation in the boiler must be so complete that the heat from the furnace may be quickly and thoroughly diffused throughout the whole body of water.
4. The construction of an engine that will use the steam without loss of heat, except so much as may be necessary to perform work required of the engine.
5. The recovery of heat from exhaust steam.
6. The absence of friction and back pressure in the working of the engine.

It is superfluous to say that these conditions are not fulfilled in any engine of the present day. At best the combustion of fuel is only approximately perfect, the losses being due to several causes among which are, — unburned fuel falling through the spaces in the grates and mingling with the ashes. This, with some kinds of coal, and improper firing, amounts to a large percentage of the furnace waste.

It is not possible with any present method of setting boilers to transfer all the heat of the furnace to the water in the boiler; nor can there be for the reason that, the temperature of the escaping gases must not be lower than that of the steam in the boilers, or direct loss will result in the radiation of heat from the tubes or flues in the boiler, by thus reheating the gases to the steam temperature.

If the steam pressure is 80 lbs. per square inch above the atmosphere, the corresponding temperature due to this pressure is 324° Fahr. The temperature of the escaping gases ought not, therefore, to be less than 350° Fahr. where they leave the boiler flues or tubes to pass off into the chimney.

If the temperature of the furnace be taken at 2000° Fahr. and the escaping gases at 400° Fahr. it will be seen that one-fifth of the heat generated in the furnace is passing off without performing work. This is a very great loss, and these figures understate rather than correctly give the loss from this one source.

Efforts have been made to utilize the temperature of these waste gases by making them heat feed water by means of coils, or by that particular disposition of pipes and connections known as an economizer. Others have turned it into account by making it heat the air supplied the fuel on the grates. Any heat so reclaimed is money saved, provided it does not cost more to get it than it is worth in coal to generate a similar quantity of heat. It is doubtful whether the loss in this particular direction can be brought below 20 per cent. of the fuel burned, at least, by any method of saving now known.

The loss by bad firing and by a bad construction of furnace is often a large one. It has been demonstrated experimentally that 20 to 30 per cent of fuel can be saved by a proper construction and

operating of the furnace. The direct causes of loss are, too low temperature of furnace for properly burning fuels, especially such as are rich in hydro-carbon gases; or, by the admission of too much cold air over or back of the fire; or by the admission of too little air under the fire so that carbonic oxide gas is generated instead of carbonic acid gas, the former being a product of incomplete, the latter the product of complete combustion.

The relative heating powers of fuel burned, resulting in the production of either of these two gases being as follows:

	Heat units.
1 pound of carbon burned to carbonic acid	14,500
1 pound of carbon burned to carbonic oxide	4,500
Units of heat lost by burning to carbonic oxide	10,000

It will be seen that here is an enormous source of loss and all that is required to prevent it is a proper construction of furnace.

Smoke is a nuisance which ought to be prohibited by stringent legislation.

There is no good reason for its polluting presence in the atmosphere, defiling everything with which it comes in contact. Smoke regarded as a source of direct loss is greatly overestimated, the fact is, the actual amount of coal lost to produce smoke is very trifling.

The presence of smoke indicates a low temperature of furnace or combustion chamber; if the temperature were sufficiently high and the furnace properly constructed, smoke could not be generated. The prevention of smoke is easily accomplished, and with it a more economical combustion of hydro carbon fuels.

Radiation.—A considerable loss of heat occurs by radiation from the furnace walls; this may be prevented in part by making the walls hollow with an air space between. If a force blast is used the air may be admitted at the back end of the boiler-setting and by passing through between the walls will become heated and if conveyed into the ash pit at a high temperature will greatly assist combustion and thus tend to a higher economy.

Air required.—In regard to the quantity of air required, it will vary somewhat with the fuel used, but in general 12 pounds of

air are sufficient to completely burn one pound of coal; practically however, 15 to 25 pounds are furnished, being largely in excess of that which the fire can use, and must pass off with the gases as a waste product.

This surplus air enters cold and leaves the furnace heated to the same temperature as that of the legitimate and proper products of combustion, and thus directly operates to the lowering of the furnace temperature.

Measurement of Heat.—A heat unit is that quantity of heat necessary to raise the temperature of one pound of water one degree, from 39° to 40° Fahr., this being the temperature of the greatest density of water. A thermal unit, heat unit, or unit of heat, all mean the same thing.

Experiments have been made to determine the mechanical equivalent of a heat unit, and it is found to be equal to 772 pounds raised one foot high. This is sometimes called "Joule's equivalent," after Dr. Joule of England, it is also known as the dynamic value of a heat unit.

Knowing the number of heat units in a pound of coal enables us to calculate the amount of work it should perform. Let us suppose a pound of coal to be burned to carbonic acid gas and to develope during its combustion 14,000 heat units, then:—

14,000x772=11,008,000 foot pounds.

That is to say: if one pound of coal were burned under the above conditions it would have a capacity for doing work represented by the lifting of eleven millions of pounds one foot high against the action of gravity. Suppose this to be done in one hour then we should expect to get from one pound of coal an equivalent of 5.56 H. P. It is well known that only a very small fraction of such equivalent is secured in the very best modern practice. The question is where does this heat go, and why is it so small a portion of it is actually utilized?

The losses may be accounted for in several ways and perhaps as follows:

The heat wasted in the chimney	25	per cent.
Through bad firing	16	"
Heat accounted for by the engine (not indicated)	16	"
Heat lost by exhaust steam	55	"
	100	

This is about 2 pounds of coal per hour per indicated horse power, which is regarded as a very high attainment and is seldom reached in ordinary cut off engines.

It requires good coal, good firing, and an economical engine to get an indicated horse power from two pounds of coal burned per hour. As coal varies in quality it is a better plan to deduct the ashes and other incombustible matter and take the net combustible as a basis of comparison.

The best coal when properly burned is capable of evaporating 15 pounds of water from and at a temperature of 212° Fahr. The common evaporation is about half that amount, and with the best improved furnaces, and careful management it is seldom that 10 pounds of water is exceeded and is to be regarded as a high rate of evaporation. In experimental tests 12 pounds have been reported, but it is doubtful whether there is any steam boiler and furnace which is constantly yielding any such results.

Circulation of water in a boiler is a very important feature to secure the highest evaporative results. Other things being equal the boiler which affords the best circulation of water will be found to be the most economical in service. Circulation is greatly hindered in some boilers by having too many tubes; in others, by introducing in the water space of the boiler too many stays and making the water spaces too narrow.

To secure the highest economy there must be thorough circulation from below upwards, in the boiler. There is no doubt that a great deal of heat is lost because the construction is such as to hinder a free flow of water around the tubes and sides of the boiler.

The construction of an engine that will use steam without loss of heat, except so much as may be necessary to perform work required of it, is a physical impossibility. Among the sources of loss in an engine are:— radiation, condensation of steam in unjacketed cylinders, and the enormous loss of heat occasioned by exhausting the steam into the atmosphere.

Radiation is usually classed among the minor losses in a steam engine. There is a considerable loss of heat caused by radiation

from steam boilers and pipes exposed to the atmosphere, and not protected by a suitable covering.

Much of this heat may be saved by employing a non-conducting material as a covering which, though not preventing all radiation, will save enough heat to make its application economical. It is well known that some bodies conduct and radiate heat less rapidly than others, but it must not be understood that the absolute value of such a covering is inversely proportioned to the conducting power of the material employed, because in its application the outer surface is enlarged and the radiation will be going on less actively at any given point, but the enlarged surface exposed reduces somewhat the apparent gain.

Covering Boilers and Pipes.—Locomotive boilers have a casing of wood around the boilers and covered with sheet iron, this makes a very good and low priced covering, and is also well adapted to portable engines.

Owing to the competition and consequent low price at which the latter engines are offered they are seldom covered in this way.

Stationery boilers generally have the side walls carried up to a height of a few inches above the top of the boiler and this space is filled in with dry ashes. There are now in the market several proprietary articles which have been found quite efficient in preventing loss by radiation, among these are air space coverings, asbestos, and others of which the composition is not made known.

Steam Jackets.—This term is commonly used to designate a steam tight casing around an engine cylinder, and which it is intended shall be kept filled with steam, that the inner cylinder shall be maintained at a temperature equal to or higher than that of the steam before expansion begins. The particular object in jacketing steam cylinders is to prevent the condensation of steam within the cylinder during any portion of the stroke.

When steam is admitted into an ordinary cylinder, the temperature of the cylinder itself is lower than that of the steam, consequently the steam gives up to the cylinder so much of its heat as may be necessary to equalize the temperature. This occasions loss of pressure, which means loss of heat, therefore, the

steam has less capacity to do work; the usual expression for this is "waste of energy." If the cylinder is surrounded by a body of steam at full boiler pressure, its temperature will be higher than that of the inflowing steam and no such condensation will take place and there will be nothing within the cylinder but dry steam throughout the stroke. Condensation is going on just the same however, but it is transferred from the cylinder where the pressure is variable, to the steam jacket, where the pressure is constant.

However satisfactory the theory of the steam jacket may be, it has not always been satisfactory in its practical workings. No doubt much of this is due to defective design, and to incompetent handling after erection. It is doubtful whether it is of any special advantage in ordinary high pressure engines cutting off not earlier than $\frac{3}{8}$ to $\frac{1}{2}$ stroke. When a large engine is working with high grades of expansion, say $\frac{1}{6}$ or $\frac{1}{4}$ cut off, then a steam jacket may be of advantage.

One thing is certain with respect to steam jackets, and that is, the water of condensation must not be allowed to collect in the jacket, and that is about the only duty devolving upon the engineer. If this is not carefully attended to, an efficient steam jacket may be made not only inoperative, but result in a greater waste through enormous condensation, than would result if the engine had no jacket at all.

It must not be supposed that the benefits occurring or likely to occur from the use of a steam jacket are confined to large engines; the reason why they are seldom applied to small engines is on account of the increased cost of manufacture, and the change required in the patterns for cylinders to be so fitted.

Condensation in Steam Cylinders.—This is a source of waste in all steam engines in which no special provision has been made to prevent it. The two methods usually employed in its prevention are either superheating the steam, or by the use of a steam jacket around the cylinder.

To entirely prevent condensation would require that the cylinder and piston be made of a non-conducting and a non-*absorbing* material, this would prevent any waste of fuel by con-

duction and radiation. Condensation occurs through another cause, and which cannot be thus remedied; that is, the condensation of steam due to the performance of work in the cylinders, but this can hardly be reckoned as a loss or waste of fuel.

So far as choice of material for a steam cylinder goes, we are practically confined to cast-iron, which is a good conducting material and absorbs heat rapidly during the first part of the stroke and as the temperature falls within the cylinder gives it out rapidly during the latter part of the stroke, if it is a cut-off engine or one in which the steam is used expansively; the loss continuing during the whole of the return stroke of the piston, and which reaches the maximum if the engine be a condensing one; the loss of heat being less if the steam be exhausted into the atmosphere with the usual two or three pounds back pressure.

The use of superheated steam has not been employed in high pressure steam engines, except in rare instances and under circumstances which cannot ordinarily be trusted, or safely confided to the care of an ordinary workmen.

The objections to a steam superheating apparatus are principally the excessive wear and tear to which it is subjected and which makes it very expensive to operate, together with the danger of accident likely to result by having a high steam pressure within an over-heated pipe or chamber, and the mischief the steam itself is likely to occasion the valves and piston by destroying the lubricating qualities of the oil between the wearing surfaces.

Exhaust Steam.—The recovery of heat from exhaust steam, and its utilization without interfering with the performance of the engine, is as yet an unsolved problem. In a non-condensing engine more than half the heat generated by the combustion of fuel in the furnace is carried away in the exhaust steam as it escapes into the atmosphere. The reduction of pressure during the entire stroke of the piston is favorable to the abstraction of heat from the cylinder during the period of exhaust, and results in greater or less loss of heat, depending on the time occupied.

This may be lessened somewhat by the early closing of the exhaust valve and thus compressing the steam up to, as near as possible, the pressure in the steam chest. A high piston speed and rapid rate of revolution will very materially contribute to economy of heat by lessening the quantity abstracted by the exhaust.

CHAP. III.

SELECTION OF A BOILER.

The selection of a boiler for a particular service will naturally suggest the following questions:—

1. What kind of a boiler shall it be?
2. Of what material shall it be made?
3. What size shall it be in order to furnish a certain power?

In reply to the first question it is to be expected there will be wide differences of opinion varying with the locality, usage, and service for which it is intended.

One of the first things to be taken into account in the selection of a boiler is the quality of water to be used in it for generating steam. If the water is pure, then it makes little difference what kind of boiler be selected so far as incrustation affects selection. If the water is hard and will deposit scale upon evaporation then a boiler should be selected which will admit of thorough inspection and removal of any deposit formed within it.

For hard water, the ordinary two flue boiler will be found a good one, as it is favorable to a thorough circulation of water, and permits easy access to all parts of it for examination and cleaning. It does not, however, present the extent of heating surface for a given space that tubular boilers offer; but with hard water the boiler is quite as economical if kept in good condition.

The difficulty with tubular boilers when used in connection with hard water is that the tubes will in a short time become coated with scale; this prevents the transmission of heat not only, but impairs the circulation of the water around them. Both of these are opposed to economy in the fact that it requires more

coal to generate a given weight of steam in the first case; and second by reason of deficient circulation, the plates over the fire are likely to become overheated and burnt and so become dangerous; thus directly contributing to accident or disaster.

The matter of circulation in boilers is one which should have careful attention in making a selection. There is little trouble in this regard with any of the ordinary types of boilers so long as they are clean and new, and properly proportioned. Nor is there likely to be any difficulty thereafter if the water is soft and clean. Circulation is often seriously impaired by putting in too many tubes in a boiler, the effect of which is to so fill up the space that the heated particles of water forcing their way upwards from below meet with so much resistance that they can hardly overcome it, and the result is that a boiler does not furnish from one-fourth to one-half as much steam for a given weight of fuel as it should, from this very cause.

Boilers intended for use in distant localities where the facilities for repairs are meager or entirely wanting, and fuel low priced, should be of the simplest description. Cylinder boilers or two flue boilers will perhaps be found most suitable. These are largely used by coal miners, blast furnaces, saw mills, and other branches of industry which must of necessity be removed from the larger towns and engineering work shops.

In selecting a boiler for a planing mill or any other place in which the fuel is of similar description and the firing irregular, there should be large water capacity in the boiler that it may act as a reservoir of power in much the same way that a fly wheel acts as a regulator for a steam engine. It is a common notion among wood-workers that firing with shavings or light fuel is "easy on the boiler." There is abundant reason to doubt this. The suddenness and the rapidity with which an intense fire is kindled in the furnace, filling all the furnace space and the tubes with flame, and with an intense heat which envelopes all within the limits of draft opening, continuing thus for a few minutes only, and as suddenly going out, can hardly be regarded as the ideal furnace. Yet there are thousands of just such furnaces at work, and it is

altogether probable that little or no change will be made in them by this class of manufacturers, at least in the near future.

In regard to the selection of a boiler for this service, we are brought back again to the question of hard or soft water. The decision should be largely influenced by this, but whatever type of boiler is selected there should be a surplus of boiler power of at least 20 per cent., that is if a 50 horse power boiler is needed to do the work, put in one of 60 horse-power, this will prevent the fluctuations of speed in the engine which are sure to follow a reduction of boiler pressure.

This increase in boiler power ought not to be simply that of tube surface, but should also include extra water space. The reserve power of a boiler is in the water heated up to a temperature corresponding to the steam pressure, when this pressure is lowered the water then gives off steam corresponding to the lower pressure, the more water the more steam, and in this way the water in the boiler stores up heat when over fired, to give it off again when the fire is low, and so acts a regulator of pressure, a thing that extra tube surface cannot do.

This kind of firing is apt to induce priming, and for this reason a boiler should be selected having a large water surface. Horizontal boilers are, in general, to be preferred over vertical ones for planing mills because of the larger water surface exposed in proportion to the heating surface. If a tubular boiler is selected, the water line above the tubes should be not higher than two-thirds the diameter of the boiler measured from the bottom, and the boiler should be made having the upper edge of the top row of tubes at least three inches below this, there should also be a clear space up through the center of the boiler of sufficient width to insure a perfect circulation of water.

Horizontal tubular boilers are to be recommended when pure soft water is used. They combine at once the qualities of great strength without excessive bracing, large heating surface, high evaporative capacity without liability to priming, and are convenient of access for external and internal examination when set in the furnace.

Boilers of this class are apt to contain too many tubes, and are thus rendered less efficient than if a smaller number were used for the same diameter of shell.

The tubes should be not less than three inches and are seldom more than four inches in diameter, when secured to the heads by expanding. The tubes may be three inches for all diameters of shell up to 48 inches; for diameters of shell ranging from 44 to 60 inches, three and a half inch tubes may be used; and for diameters of shell from 48 to 72 inches the tubes may be four inches in diameter.

In regard to length, 3 inch tubes may be used up to 12 to 14 ft; 3½ inch tubes from 12 to 16 feet long, and 4-inch tubes from 14 to 18 feet long.

The space between the tubes should be at least one-third their diameter, and there should be ample space between the nearest tube and the shell for circulation of water up the sides of the boiler; a center space should also be allowed in boilers of large diameter, say in all boilers over 48 inches in diameter.

Flue boilers are not regarded as being quite so economical as tubular boilers. In a "competitive test" they would probably be "figured out" on the score of economy, yet with all their apparent want of economy they are not to be despised; on the contrary, there are circumstances or conditions in which they are to be strongly recommended. Chief among the the advantages claimed for this style of boiler may be mentioned the fact that it affords every possible facility for examination and cleaning. In this respect it is second only to the cylinder boiler.

Boilers of this kind should be fitted with two man heads; one at the back end above and the other at the front end underneath the flues.

The principal danger connected with this kind of a boiler is the liability of the flues to collapse, and for this reason the boilers should not be made excessively long, nor of very large diameter of flues. The commonest diameters for two flue boilers are from 40 to 44 inches; the flues are usually one-third the diameter of the shell; the lengths do not as a general thing vary much from six

times the diameter of the shell. These may be taken as fair average proportions.

Five Flue Boilers.—Boilers are also made with several large flues, perhaps the five flue boiler is the oftenest met with; the arrangement being that of three large flues above and two smaller ones below. This is not a very desirable form of construction, and has little to recommend it over the two flue boiler.

Instead of a five flue boiler, it is perhaps preferable to take the same diameter of shell and insert as many six inch lap-welded flues as it will contain allowing three inches water space between the flues and the side of the shell.

Boilers of this kind may be made from 16 to 20 feet long and will be found to be a good style of boiler.

Fire box boilers, or locomotive boilers as they are commonly called are best adapted for small powers and with a fuel which deposits but little soot in the tubes. This kind of boiler is supplied with portable or agricultural engines and is very well adapted for that particular service.

In canvassing the desirability of this kind of a boiler for stationary use, we must again refer to the kind of water to be used in it. If the water is soft and clean there is then no particular objection to a boiler of this construction being used for small powers; if the water is hard and will form scale it ought not to be chosen, but a flue boiler selected instead.

Vertical boilers are used in great numbers for small engines, heating, etc. They have the merit of being compact and low priced. A common defect in the construction of this kind of boiler is that too many tubes are put in the head in the fire box, thereby preventing a proper circulation of water between them. This defect in construction induces priming with all its attendant annoyances and dangers.

This style of boiler is not suited to hard water, but pure soft water only. If the water is hard an upright boiler with a single flue is better if not safer than the tubular boiler. These boilers

should be provided with hand holes above the crown sheet and around the bottom of the water legs; at least three at each place mentioned.

Boiler Material.—In regard to the material of which a boiler shall be made there is but the simple choice between iron and steel.

If iron should be selected, it should be of a grade not lower than C. H. No. 1, and capable of withstanding a tensile strain of at least 40,000 pounds per square inch of section lengthwise of the grain of the metal. It should also show a contraction of area at the point of fracture of at least twelve per cent. This is the lowest grade of iron which should enter into boiler construction.

It sometimes happens in giving the tensile strength of iron that no other facts are given, such as contraction of area, etc. It was formerly the practice to break specimens in order to arrive at the tensile strength only, but extended observation has shown that this alone does not indicate the quality, and that poor irons are quite as likely to show a high breaking strain as better ones. It is now considered the best practice to take into account both these qualities when testing iron boiler plate.

There are now three kinds of steel in the market—crucible, Bessemer, and open hearth steel. On account of the small quantity made and the high price charged for the first; the little effort made to sell the second; the open hearth steel practically rules the market. It has many qualities which admirably fit it for boiler construction, and will no doubt always hold a leading place among boiler materials.

Steel for boilers should not be of too high tensile strength; 60,000 to 65,000 pounds tensile strength per square inch makes the best boilers. If the steel is of too high a grade it will take a temper and therefore is utterly unfit for use in steam boilers; if the steel is of two low tensile strength it is apt to be loose or spongy.

Among the advantages steel possesses over iron may be mentioned the circumstance that it is a practically homogeneous material when properly made and rolled, consequently it is nearly

as strong in one direction as it is in another. In this respect steel is superior to iron plate of equal thickness because the latter is made up of several pieces of iron welded together and in rolling into the plate it becomes fibrous and thus of unequal strength, being greatest in the direction of the fiber and least when tested across it.

Boiler Power.—In regard to the size of a boiler it is not easy to give "off hand" advice, yet this is a question of great importance and one about which the purchaser is more directly concerned than almost any other, because it affects price. It is no economy to buy a boiler too small for the work it has to do in order to save something in first cost; neither is it economy to get too much boiler power for the work.

The size required for any particular service will depend largely upon its construction, except in the case of small powers, boilers are as a general thing either horizontal flue or tubular. For ordinary slide valve engines it is considered a safe practice to allow for:—

Cylinder Boilers,	9 square	feet	heating	surface	per	H. P.	
Flue Boilers	12	"	"	"	"	"	"
Tubular Boilers	15	"	"	"	"	"	"

These proportions vary somewhat in different localities and among different builders. If an automatic cut-off engine is to be used the boilers may be reduced about one-third from the above proportions to furnish the steam for the same indicated horse power.

The horse-power of a boiler is a rating which should never have been introduced, as it is the engine and not the boiler which gives us power in motion.

If a boiler is to supply steam to an ordinary slide valve engine it will require not far from 60 pounds of water to be evaporated to furnish a horse-power; if this same boiler were to supply the steam for an automatic cut-off engine using a moderate high pressure and working expansively, then 30 pounds of water evaporated will be ample for a horse-power; so that for a given boiler, it might be a 25 H. P. boiler to one purchaser and a 50 H. P. boiler

to another, depending altogether on the kind of engine it was to be used in connection with. Experts in making out their reports of experimental tests usually consider an evaporation of 30 pounds of water equivalent to one horse-power.

Boilers ought to be somewhat larger than just sufficient for an engine as sudden reductions of pressure in a boiler are likely to induce priming, and thus endanger the boiler not only but the engine as well.

CHAP. IV.

BOILER APPENDAGES AND THE FURNACE.

The common appendages to a steam boiler are a safety valve, feed and blow-off pipe, steam pipe, guage cocks, glass water guage and steam guage; to which may be added a steam drum or dome and a mud drum.

There are numerous other devices which are attached to boilers such as safety guages, alarms, fusible plugs, automatic dampers, etc.; many of these are very servicable and are well liked by those using them.

Safety Valves should always be large enough to permit the escape of all the steam a boiler is capable of making and each boiler should have its own safety valve rather than connecting two or more boilers together and depending on one valve for the whole.

The valve and seat should be made of hard gun metal or any other composition that will not rust and stick fast. At one time it was quite a common thing to see a brass valve fitted to a cast iron seat; this is wrong for the rusting of the iron would fix the valve so tightly that the boiler would be in constant danger of rupture from over pressure.

For stationary boilers the common ball and lever safety valves are generally used; a hole should be drilled in the end of the lever and a cord attached, which can be led over a series of small pulleys to the fire or engine room and thus allow it to be raised several times a day. In case it is necessary at any time during

working hours, or at noon time, to stop the engine, the safety valve should be raised from its seat to be sure that it is in good working order.

For stationary boilers it is immaterial whether the safety valve be fitted with a lever and weight, or whether it be fitted with a spring. The former is the usual manner of loading a safety valve and has but few objections. For portable engines and locomotives safety valves are loaded with springs which by suitable adjustment may be made to blow off at any desired pressure.

The following rule is that enforced by the U. S. Government in fixing the area of safety valves for ocean and river service, when the ordinary lever and weight safety valve is employed:

RULE.—When the common safety valve is employed it shall have an area of not less than one square inch for each two feet of grate surface.

Another rule, ascribed to Professor Thurston, is to multiply the pounds of coal burned per hour by 4; this product is to be divided by the steam pressure to which a constant number 10 is added.

Example: What would be the proper area for a safety valve for a boiler having a grate surface 5 feet square and burning 12 pounds of coal per hour per square foot of grate; the steam pressure being 75 pounds per square inch?

5 x 5=25 square feet of grate.

25 x 12=300 lbs. of coal per hour.

300 x 4=1200.

75 + 10=85=steam pressure with 10 added, then $\frac{1200}{85}=14.11$ inches are or 4¼ inches diameter.

The feed pipe usually enters the boilers at the rear end, and is commonly screwed into a hole tapped into the back head. For large boilers or where several boilers are fitted together in one battery, flanges are sometimes used, but this is the exception rather than the rule.

A feed pipe should be at least twice the area over that which is regarded as simply necessary to supply the boiler with water, as

sediment or scale is likely to form in it which will materially reduce its area.

In localities where the water is hard the feed pipes should be disconnected near the boiler and examined occasionally to ascertain whether or not scale is forming in them.

In general, the sizes of feed pipes leading from the pump to the boiler are fixed by the size of tap used by the maker of the pump. It is not well to reduce the diameter of the pipe, and the size should be the same throughout. Care should be exercised in putting pipes in place that no strain be brought upon them by imperfect fitting as it is certain to lead to leaky joints at some time or another. It is also desirable that the pipes be as short and straight as possible. Feed pipes should never be placed under ground if it is possible to make any different disposition of them. In locating pipes it is desirable to arrange for the expansion of the boiler as well as for that of the pipes themselves.

In selecting a pump it should have a much larger capacity than that needed to supply the boiler as there are many things which affect the working of a pump, such as defective suction pipes, leaky valves, etc. It is the practice of most manufacturers to give the capacity of their pumps in gallons of water delivered per minute from which it is easy to select a suitable size, but the speed given in the tables at which the pump is to run is generally faster than that which it is desirable to run them.

As a general thing, and without referring to any particular maker or design, it is a good plan to select a pump having four times the capacity actually needed for the boiler, then the speed may be reduced to half that given in the table, and will require less repairs, and will be a more satisfactory purchase in the long run.

In selecting an injector or inspirator the size should not greatly exceed that actually required to supply the boiler. In making the steam connections the pipes should start from the steam space of the boiler, and should not be branches merely from the other steam pipes, neither should the diameters of the pipes be less

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than that which the instrument calls for. The pipes should be as short and straight as practicable; abrupt bends should always be avoided in the suction pipe.

If the water is taken from a stream in which there are floating particles of wood, leaves, etc., a strainer should be used; a large sheet metal box with perforated sides makes a good strainer; the openings ought not to greatly exceed an eighth of an inch in diameter, and should be several times the area of the suction pipe.

A Check Valve should be fitted with a cock between it and the boiler, so that in the event of its not working satisfactorily it may be taken apart, cleaned, and replaced without stopping for examination or repairs.

The Blow-off Pipe should be so arranged that it will entirely drain the boiler of water; it is also a good plan to set a boiler with a slight inclination toward the blow-off pipe that it may be thoroughly drained; an inclination of two inches in twenty feet works well in practice. The blow-off pipe is usually fitted at the back end of the boiler. It is a common practice to fit a piece of pipe into the back head, and attach a T fitting to it, feeding into one branch and using the other for the blow-off.

The Steam Pipe may be connected at any convenient point on the top of the boiler. If the boiler is to furnish steam for an engine only, the common practice is to make the diameter of the pipe one-fourth that of the cylinder. The steam pipe should be as short and straight as possible. If bends are to be introduced in steam pipes it is better to have a long curved bend than the abrupt right angle fitting usually employed for the purpose. It is also a good plan to provide a stop-valve next the boiler to shut off the steam and prevent it condensing in the steam pipe at night, or other long stoppages.

The Gauge Cocks should be not less than three in number, and may be of any of the various kinds now in the market. For stationary boilers the Mississippi gauge-cock is, perhaps, as good as any. For portable engines a compression gauge-cock is perhaps the best. The lower gauge-cock should be at least one inch above

the tubes or crown sheet, the middle one at the ordinary water line, the upper one at any convenient distance above it, say from one to three inches, depending on the size of the boiler.

A Glass Water Gauge should be provided for each boiler, and should be so located that the water level in the boiler when at the lower gauge-cock shall then be on a line with the top of the lower stuffing box gland. When glass gauges are so fitted the fireman can always tell at a glance just how much water he has above the flues or crown sheet; it also permits the easy test of accuracy by trying the gauge-cocks with the water at a certain known level. Too much dependence must not be placed on the glass water gauge alone, but should be used in connection with the gauge-cocks.

A Steam Gauge is a very important appendage to a steam boiler, and should be chosen with special reference to accuracy and durability. The two ordinary gauges now in the market are the bent tube and the diaphragm gauges. It matters little which of the two kinds is selected provided it is a good and first-class gauge. A steam gauge should be compared with a standard test gauge at least once a year, to see that it is correct. The importance of this will be fully apparent when it is known that it furnishes the only means by which the fireman is to judge of the steam pressure in the boiler. A siphon should be attached to every gauge, and provision should also be made for draining the gauge or siphon to prevent freezing when steam is off the boiler. Neglect of this may endanger the accurate reading of the steam gauge and render it useless.

Steam Dome.—This is a reservoir for steam, riveted to the upper portion of the shell and communicating, by a central opening with the steam space in the boiler. When this reservoir forms a separate fixture and is attached to the boiler by cast or wrought iron nozzles, it is then called a *steam drum.* The latter answers all the purposes for stationary boilers that the former does, and is to be preferred because of the smaller opening in the shell of the boiler. A considerable number of boiler explosions

have been traced directly to the weakness of the shell caused by the large opening in and imperfect staying of the shell underneath the dome. When a dome is employed and has a large hole underneath, the strength of the shell is impaired in two ways. 1. By reducing the longitudinal sectional area of shell through the center of opening cut for it, which weakness can not wholly be made good by a strengthening ring around the opening. 2. By causing a tension equal to that on the crown area of steam dome, upon the annular part of the shell covered by the flange of the dome. The weakest part of the boiler shell will be where the distance from rivet hole at the base of the dome to edge of plate is least. It is difficult, owing to the complex nature of the strains, to form a rule whereby to determine how much the strength of the shell is impaired by using a dome; but it is quite apparent from general experience that they are in many cases a source of weakness, and the larger the dome connection with the shell, the greater the liability to rupture.

This tendency to rupture is due to the fact that the dome, with its connecting flange, is practically inelastic; that portion of the shell of the boiler covered by the dome is, as soon as the pressure is introduced on both sides of the plate, simply a curved brace. The pressure of the steam in the boiler, has a tendency to straighten the shell under the dome and thus brings about a series of complex strains which are not easily remedied by any system of bracing, so that on the whole it is preferable to use a small connecting nozzle with a drum above it, rather than to rivet a large dome directly to the shell.

Dry Pipe.—This is a pipe having numerous small perforations on its upper side, and inserted in the upper part of the steam space of the boiler. This pipe does not dry the steam, but acts mechanically by separating the steam from the water when the latter is in a violent state of agitation, and is liable to be carried in bulk toward or into the steam pipe. The object of these numerous small holes in the pipe is that a small quantity of steam may be taken from a large number of openings at one time, and thus carried over a larger extent of surface than that afforded by a single opening, and by this simple device checking the tendency to

priming. This pipe leading from the boiler is sometimes carried through the combustion chamber under the boiler, and from thence to the engine; a practice which is not recommended under any ordinary circumstances.

Steam Boiler Furnaces are receiving more attention now than perhaps ever before. The question of economy of fuel is being closely studied, and there is now an effort to save much ot the heat which had formerly been allowed to go to waste.

The main thing in furnace construction is to get perfect combustion. Without this there must be of necessity a great loss constantly going on. There are some losses which it is difficult to prevent, for example—the loss by the admission of too much air in the ash pit; the loss by incomplete combustion; the loss occasioned by the heated gases escaping up the chimney, the loss by radiation; but chief among these is that of incomplete combustion.

To burn a pound of coal requires about twelve pounds of air, or say 150 cubic feet. Most boiler settings permit from 200 to 300 feet to pass through the fire. It is needless to point out the great source of loss arising from this one cause alone. This may be prevented in a measure by having a suitable damper in the chimney and regulating the flow of escaping gases by it instead of the ash pit doors.

If the furnace is so constructed that the fuel is imperfectly burned, so that carbonic oxide instead of carbonic acid gas is formed the loss is very great, as shown on page 16. This results often from too little air supply and too low temperature in the furnace. The furnace doors should be provided with an opening leading into the space between the door proper and the liner; this opening ought to have a sliding or revolving register by which the admission of air may be controlled. By this means the quantity of air admitted above the fire may be adjusted to its needs by a little attention on the part of the fireman. The liner to the furnace door should have a number of small holes in it rather than a solid plate, with a space around the edges.

Great care should be exercised in the construction of furnace walls that the materials and workmanship be good throughout. The entire structure should be brick including the foundations.

The outer walls may be of good, hard, red brick, but the interior walls around the furnace and bridge walls should be of fire brick.

The best quality of fire brick for withstanding an intense heat are never very strong and tenacious; the structure is open and they are free from black spots, due to sulphuret of iron in the clay; if well burned they will not be very light colored on the outside, and will have a clear ring when struck.

Fire brick should be laid up in a thin mortar made of fire clay rather than in a lime and sand mortar such as is used in ordinary red brickwork.

In laying up those portions of a boiler furnace requiring fire brick, provision should be made in the original wall for replacing the fire brick and without disturbing the outer brickwork.

Grate Bars are as a general thing made of cast iron, two or three being combined in a single casting.

There are many fanciful designs for grate bars which appear from time to time, and many absurd claims are advocated in their behalf. The only possible advantage which such a grate-bar could possess over a well designed ordinary bar would seem to be that of durability, or strength to resist the action of intense heat. It is better for deep furnaces to have two sets of short grate-bars than one set of long ones; that is, if a furnace is five or six feet deep to have two lengths of grates of half the former length. This will prevent the distortion of the grate surface by the twisting or bending which is almost sure to occur with long bars. The thickness of metal on the top of the grate-bars is from $\frac{5}{8}$ to $\frac{3}{4}$ inch for about half an inch down, when it is gradually thinned to about 5–16 inch thick at the lower edge. The space between the bars is usually half an inch. As a general thing the same bars are used for all kinds of fuel.

Rocking, revolving, reciprocating and other forms of grate-bars are in use in many localities and are working very satisfactorily. These are proprietary designs and are furnished only by the manufacturers or their agents.

The Bridge Wall is a wall of fire-brick built up at the rear end of the grates, to within about a foot of the under side of the boiler.

It is not customary to give it a curve, but it is carried straight across the furnace from side to side. This wall is sometimes built hollow with an air space communicating with the atmosphere; the wall being fitted either by a perforated plate or a narrow opening made by the brick layer so as to permit a flow of heated air through the bridge wall into the combustion chamber.

Sometimes a wrought iron water back is employed with water pipes connecting with the boiler, but as a general thing the wall is simply solid brickwork. The exact height to which a bridge wall is to be carried will depend upon the kind and quantity of fuel burned, and if the ordinary distance of twelve inches from the boiler does not give the best results it may be changed by simply laying on or taking off a layer or two of bricks on the top.

At the rear end of the boiler another wall is built; this has a curved top following the curve of the boiler; the area of this opening may be about one-sixth of the grate area. The space between this wall and the bridge wall is called the combustion chamber. This chamber should be as large and roomy as possible to insure a perfect diffusion of gases and prevent a too rapid current beneath the boiler.

Chimneys should have an area of about one-eighth that of the grate area; and if of wrought iron it should be about 25 diameters high, and should be provided with a wrought iron band one-third the distance from the top, to which are to be secured three guy rods; these are best made of wrought iron rods linked together with welded rings or eyes; the diameters will vary from 5-16 to ½ inch, depending upon the height and weight of the stack.

CHAP. V.

CARE AND MANAGEMENT OF A BOILER.

It is not enough that a boiler be of approved design, made of the best materials and put together in the best manner; that it have the best furnace and the most approved feed and safety apparatus. These are all desirable and are to be commended, but cleanliness and careful management are quite essential to getting high results and are also conducive to long use in service.

Pumps.—Special attention should be given at all times to the feed and safety apparatus; the pumps should be in good working order; it is preferable that they be independent steam pumps rather than pumps driven by the engine or by a belt; they should be kept well packed and the valves in good condition.

Firing.—Kindle a fire and raise steam slowly; never force a fire so long as the water in the boiler is below the boiling point. The fire should be of an even height, and of such a thickness as will be found best for the particular fuel to be burned, but should be no thicker than actually necessary. In regard to the size of coal used, that will depend upon circumstances. If anthracite coal is used it should not, for stationary boilers, be larger than ordinary stove coal. For bituminous coal, which is always shipped in lumps as large as can be conveniently handled, the size will vary somewhat in breaking, but it may in general be used in larger lumps than anthracite.

If the coal is likely to cake in burning the fire should be broken up quite frequently with a slice bar or it will fuse into a large mass in the center of the furnace and lower the rate of com-

bustion. If the coal is likely to form a considerable quantity of clinker, or enough to become troublesome, it may be advantageous to increase the grate area and thus lower the rate of combustion per square foot of grate, and have a fire of less intensity.

The fire should be kept free from ashes, and the ash pit should be kept clean.

Whenever the fire door of a steam boiler furnace is opened, the damper should be closed to prevent the sudden reduction of temperature underneath, which is likely to injure the boiler by contraction, and thus render it likely to spring a leak around the riveted joints. Some firemen are very careless in this respect, and there is little doubt that many a disagreeable job of repairing a leaky seam, might be prevented by this simple precaution.

Gauge Cocks should be used constantly to keep them free from any accumulation of sediment. It is a very common practice to rely wholly on the indications of the glass water gauge for the water level in the boiler. This is all wrong, and should be discontinued if once begun. The glass water gauge serves a very useful purpose, but it should not be wholly relied on in practice. In using the ordinary gauge cocks, the ear, more than the eye detects the water level, and thus acts as a check on the indications given by the glass gauge.

Water Gauges should be tested several times during the day to see that they are clear, and to keep them free from any sediment likely to form around the lower opening to the water in the boiler. If this is not attended to the water gauge is likely to indicate a wrong water level and a serious accident may be the result.

Steam or Pressure Gauges are likely to become set after long use and should be tested at least once, or better still, twice a year by a standard gauge known to be correct. They should also be tested every few days if the boilers are constantly under steam by turning off the steam and allowing the pointer to run back to zero. If there are two or more boilers set together in one battery, and each boiler has its own steam gauge, and which will, starting from the zero point, indicate the same pressure on all the gauges, they may be assumed to be correct.

Blow-off Cocks or valves should be examined frequently and should never be allowed to leak. In general a cock is to be perferred to a valve, but if the latter is selected it should be some one of the various "straight-way valves" of which there are now several in the market. If the cock is a large one, and especially if it has either a cast iron shell or plug, it should be taken apart after each blowing out of the boilers, examined, greased with tallow and returned.

Blowing Out.—This should be done at least once a month, except in the very rare instances in which water is used that will not form scale. The boiler should not be blown out until the furnace is quite cold, as the heat retained in the walls is likely to injure an empty boiler directly by overheating the plates, and indirectly by hardening the scale within the boiler.

Bad effects are likely to follow when a boiler is emptied of its water before the side walls have become cool; but greater injury is likely to result when cold water is pumped into an empty boiler heated in this manner.

The unequal contraction of the boiler is likely to produce leaky seams in the shell and to loosen the tubes and stays. It is a better plan to allow the boiler to remain empty until it is quite cold, or sufficiently reduced in temperature to permit its being filled without injury. Many boilers of good material and workmanship have been ruined by the neglect of this simple precaution.

Fusible Plugs should be carefully examined any time the water is blown out of the boiler, as scale is likely to form over the portion projecting into the water space. It is only a question of time when this scale would form over the end of the plug and thick enough to withstand the pressure of steam and thus fail in the accomplishment of the very object for which it was introduced. This applies especially to the fusible plugs inserted in the crown sheets of portable engine boilers.

Cleaning Tubes.—This should be done every day if bituminous coal is used. A portable steam jet will be found an extremely useful contrivance which will keep them reasonably clean by

blowing out the loose soot and ashes deposited in the tubes. Every two or three days or at least once a week, a tube scraper or stiff brush should be used to take out all the ashes or soot adhering to the tubes and which cannot be blown out with the jet. Flues may be cleaned the same way but will not require to be done so frequently.

Low Water.—If from any cause the water gets low in the boiler, bank the fires with ashes or with fresh coal as quickly as possible, shut the damper and ash pit doors and leave the fire doors wide open; do not disturb the running of the engine but allow it to use all the steam the boiler is making; do not under any circumstances attempt to force water in the boiler.

After the steam is all used and the boiler cooled sufficiently to be safe, then the water may be admitted and brought up to the regular working height; the damper opened and the fires allowed to burn, and steam raised as usual; provided no injury has been done the boiler by overheating.

Foaming or priming is always troublesome, and often dangerous. Some boilers foam almost continually because of their bad proportions, and will require the constant care of the person in charge, especially at such times as the engine may be using the steam up to the full capacity of the boiler. In a case of this kind an increase of pressure will often check but will not entirely prevent it; nothing short of an increase of water surface, or a better circulation of water, or a larger steam room will afford a complete remedy. If the foaming or priming is due to a sudden liberation of steam, or on account of impure feed water, it may be checked by closing the throttle valve to the engine and opening the fire door for a few minutes. The surface blow may be used with advantage at this time, by blowing off the impurities collected on the surface of the water. The feed pump may be used if necessary, but care should be exercised that too much cold water be not forced into the boiler, and thus lose time by having to wait for the accumulation of the regular steam pressure required for the engine.

The dangers attending foaming or priming are:—the laying

bare of heating surfaces in the boiler, and of breaking down the engine by working water into the cylinder. The commonest damage to the engine being either the breaking of a cylinder head, or the cross head, or the breaking of the piston.

When boilers are new and set to work for the first time priming is a very frequent occurrence; in fact it may be said that for the first few days there is always more or less of it. All that is needed during this time is a little care on the part of the attendant to see that the water is kept up to the required level in the boiler; it is also recommended that the throttle valve to the engine be partially closed to prevent any very great variation of pressure in the boiler, and thus prevent water passing over with the steam in such quantities as to become dangerous.

If a boiler continues to prime after it has had a weeks work and then thoroughly cleaned, the causes are to be attributed to other than the grease and dirt in it, which are inseparable from the manufacture.

As already said, priming may be caused by a sudden reduction of pressure; that is, a boiler may be working smoothly and well with, say 80 pounds pressure; if an increase of load be suddenly applied to the engine so as to reduce the pressure to 70 or 60 pounds, this sudden reduction of pressure will almost always cause priming; the less the steam space in the boiler the greater the tendency to prime, and the greater the difficulty in checking it. The only permanent cure for this is more boiler power; as a temporary expedient the engine should be throttled sufficiently to make the drain upon the boiler constant instead of intermittent. If the duty required of an engine is irregular, the steam pressure should be carried higher; in any case similar to the above it is recommended that the pressure be increased to 90 or 100 pounds and the throttling to begin with the increased drain upon the boiler. But this is at best a mere make shift, and the larger boiler power becomes imperative both on the score of economy and safety.

Water is composed by weight of

Hydrogen	11.111 +
Oxygen	88.888 +
	100.

Between 32° and 212° Fahr. and at ordinary atmospheric pressure, water is liquid; below 32° Fahr. it freezes, the ice occupying a larger bulk than the same weight of water and is the reason why it floats. Above 212° F. water is converted into steam. The greatest density of water is at 39.2° F. At 60° F. water weighs 62.35 lbs. per cubic foot, or 9.33 lbs. per gallon (231 inches).

Water is never pure, except when made so in a laboratory or by distillation; the impurities may be divided into four classes: 1, mechanical impurities; 2, gaseous impurities; 3, dissolved mineral impurities; 4, organic impurities.

a. Mechanical impurities may be both mineral and organic. The commonest suspended impurity in water is mud or sand, these may be removed by filtration or by allowing the water to stand long enough to let them settle to the bottom of the tank or cistern and then carefully drawing the water from the top, and without disturbing the bottom.

b. Gaseous impurities in water vary somewhat according to the localities from which they are obtained. The commonest gases found in the water are an excess of oxygen, nitrogen, and carbonic acid. These have no effect on water intended for steam boilers.

c. Dissolved mineral impurities in water are of the most varied description and are almost always found in it. Among these are found salts of iron, sulphate and carbonates of lime, sulphate and carbonates of magnesia, salt and alkalies, such as soda, potash, etc.; acids, such as sulphuric, phosphoric and others. All of these are more or less injurious to steam boilers. The most objectionable are the salts of lime and magnesia which impart to water that property known as hardness. When such water is used in a steam boiler a scale will gradually form, which will in a short time become very troublesome.

d. Organic impurities are present to a certain extent in most waters. They are sometimes present in the water in sufficient quantities to give it a very decided color and taste.

The presence of organic matter in water is often dangerous to health and may be a means of spreading contagious diseases, but has little or no bad effect in any water used for steam boilers.

In general water is regarded by engineers as being either soft, hard or salt.

Salt water contains not only salt but chloride of magnesium, bromide of sodium, sulphate of potash, sulphate of magnesia, and sulphate of lime. The scale formed by this water is very hard, and troublesome to remove. It is generally loosened in the boiler by means of a pick and then washed out through the hand holes at the bottom of the boiler.

Ebullition is the motion produced in a liquid by its rapid conversion into vapor. When heat is applied to the bottom of a boiler the particles of water in contact with the plates become heated and immediately expand and becoming specifically lighter pass upwards through the colder body of water above; the heat of the furnace is in this way diffused throughout the whole body of water in the boiler by a translation of the particles of water from below upwards, and from top to bottom in regular succession. After a time this liquid mass becomes heated to a degree in which there is a violent agitation of the whole body of water, steam is given off, and it is said to boil.

The temperature at the boiling point of water, at ordinary atmospheric pressure, is 212° Fahr. and increases as the pressure of steam above it increases.

Distilled water for boilers is not to be recommended without some reservation. Chemically pure water and especially water which has been redistilled several times has a corrosive action on iron which is often very troublesome.

The effect on iron plates by the use of water several times redistilled, such for example as that supplied by surface condensers, is well known; information is yet wanting which shall point with certainty to the exact change which the water undergoes, and explain why its action on, or affinity for iron is so greatly intensified. It has been suggested, as a means of neutralizing this corrosive action of the water to introduce with the feed other water which shall have the property of forming a scale, and continuing it long enough and at such intervals as will permit the formation of a thin scale in the interior of the boiler.

However objectionable this may seem at first sight, it is at present the best practical solution of the difficulty.

Scale is a bad conductor of heat and is opposed to economical evaporation. It is estimated that a thickness of half an inch of hard scale firmly attached to a boiler plate will require a temperature of about 700° Fahr. in the boiler plate in order to raise and maintain an ordinary steam pressure of 75 pounds.

The mischevous effects of accumulated scale in the boiler, especially in the plates immediately over the fire are, (1) preventing the water from coming in contact with the plates and thus directly contributing to the overheating of the latter, and (2) by causing a change of structure in the plates and the consequent weakening brought about by this continued overheating, which would in a short time render an iron or steel plate wholly unfit for use in a steam boiler.

The two principle ingredients in boiler scale are lime and magnesia. The lime when in combination with carbonic acid forms carbonate of lime; when in combination with sulphuric acid it then becomes sulphate of lime. This is also true of magnesia.

Carbonate of lime will form in the boiler as a loose powder which is held mechanically in suspension; while in this stage it may be blown out of the boiler without injury to it; but it is seldom that a pure carbonate is formed in the boiler as there are usually other impurities in the water with which it combines to form a hard scale. This is especially true in such waters as also contain sulphate of lime in solution. This fine powder, (carbonate of lime), will form a hard scale should any adhere to the sides or bottom of a boiler, in any case where the boiler is blown out dry while the furnace walls are still hot, and this in itself forms an excellent reason why boilers should stand until the furnace walls are cold before blowing out. When emptied, nearly or all of this slushy deposit may be washed out of the boiler by means of a hose.

Sulphate of lime is not so easily got rid of as it is heavier than carbonate of lime and adheres to the plates while the boiler is at work. It is the most troublesome scale steam engineers have to deal with, it is very difficult to remove and by successive layers becomes dangerous on account of the thickness to which it eventually accumulates.

The carbonates of lime and magnesia may be largely arrested by

passing the feed water through a suitable heater and lime extractor. It must be apparent to every one that any device which will accomplish this is a very desirable attachment to a steam boiler. As it is not possible to eliminate all the foreign matter in the water from it, recourse is often had to the use of solvents, and chemical agencies for the prevention of scale. Some of these are very simple and within easy reach, others are surrounded by an atmosphere of uncertainty and the real nature of the compound is hidden under a meaningless trade mark.

For carbonate of lime potatoes have been found to be very serviceable in preventing the formation of scale; its action appears to be that of surrounding the particles of lime with a coating of starch or gelatine and thus preventing the cohesion of these particles to form a mass. Various astringents have been used for this purpose, such as extracts of oak and hemlock bark, nutgalls, catechu, etc., with varying success.

The following is said to be a good preventive for boiler scale:—

One hundred pounds of logwood, mahogany or oak sawdust, twenty pounds of sal soda, and ten pounds of yellow ochre—the sawdust to be dry, mixed with the sal soda and ochre, and ground in a burr mill to the consistency of shorts used as horse feed. It may be used once a week, in seven pound charges the first five weeks, and five pound charges once a week thereafter;—it may be introduced either through the safety valve if of the ordinary weight and lever description, or through the man hole.

Carbonate of soda has been used and with very great success in some localities, not only in preventing but in actually removing scale already formed. It acts on carbonate of lime not only, but on the sulphate also. It is clean, free from grit, and is quite unobjectionable in the boiler, one or more pounds per day depending on the size of the boiler, may be admitted through the pump with the feed water, or, admitted in the morning before firing up, by simply mixing with water and pouring it into the boiler through the safety valve or other opening.

Tannate of soda has been similarly employed and is an excellent scale preventive. It will also act as a solvent for scale already formed in the boiler, acting on sulphate as well as carbonate of *lime.*

Crude petroleum has been found very beneficial in removing the hard scale composed principally of sulphate of lime.

Zinc in Steam Boilers.*—The employment of zinc in steam boilers, like that of soda, has been adopted for two distinct objects, (1) to prevent corrosion, and (2) to prevent and remove incrustation. To attain the first object it has been used chiefly in marine boilers, and for the second chiefly in boilers fed with fresh water.

In order that the application of zinc in marine boilers may be effective it is necessary that the metallic contact should be insured. If galvanic action alone is relied upon for the protection of the plates and tubes, it will doubtless be diminished materially by the coating of oxide that exists between all joints of plates, whether lapped or butted, and also between the rivets and the plates.

Assuming the preservative action of zinc to be proved when properly applied, we have now two systems for preventing the internal decay of marine boilers, viz: allowing the plates and tubes to become coated with scale, and employing zinc. It remains to decide which of these two systems is the best with respect to economy and practicability.

We come now to consider the use of zinc for preventing and removing incrustation. The application of zinc for this purpose has been extremely limited in this country, but in Europe it has been pretty extensively adopted, mainly in stationary boilers, and as may be expected with very different and conflicting results.

In some cases the use of zinc has been attended with great success in preventing and removing scale, in others no beneficial effect could be perceived, whilst in others again it has done more harm than good.

At one time it was considered that the action of zinc in preventing incrustation was physical or mechanical.

The particles of zinc as it wasted away were supposed to become mixed amongst the solid matter precipitated from the water in such a manner as to prevent it adhering together, so as to form a hard scale, or the particles of zinc were supposed to become deposited upon the plates, and so prevent the scale from adhering

*Condensed from Engineering.

to them. Then it was suggested that the zinc acted chemically, and now it is the generally received opinion that its action is galvanic in preventing incrustation as well as in preventing corrosion.

When the water contains an excess of sulphates or chlorides over the carbonates, the acid of the former will form soluble salts with the oxide of zinc, the surface of the zinc will be kept clean, and the galvanic current, to which the efficiency of the zinc is due will be maintained. On the other hand should there be a preponderating amount of carbonates, the zinc will be covered first with oxide, then with carbonates, and its useful action arrested and stopped.

It is quite as important that the zinc should be in metallic contact with the plates when used to prevent incrustation as when employed to prevent corrosion. The application of zinc for the former purpose should never be attempted without first having the water analyzed in order to ascertain whether it is likely to be effective. The use of zinc in externally fired boilers should be attempted with great caution, as when efficacious in preventing the formation of a hard scale, it is liable to produce a heavy sludge that may settle over the furnace plates and lead to overheating. On the whole we cannot but regard the evidence as to the effect of zinc upon incrustation as being very conflicting.

Evaporative Tests.—It is important that everything be got in readiness before the day fixed for the test. The boiler should be perfectly clean and tight; the grates in good condition; the draft under perfect control; the water supply arranged so that the quantity used may be either weighed or measured; the former is to be preferred. The coal should be of uniform size and quality and carefully weighed when delivered to the firemen. The temperature of the feed water should be taken at least every half hour by means of a thermometer previously tested and known to be correct. The pressure of steam should be kept as near constant as possible, and special precautions should be taken that the steam gauge be correct in its readings.

Calorimeter tests should be made frequently to ascertain the dryness of the steam.

Short boiler tests are always more or less unsatisfactory, they

ought to extend over at least 8 hours continuously, or better still 10 hours. Steam should be raised on the boiler to the intended pressure, the fire "hauled," and a new one kindled on clean grates. The depth of the fire will depend upon circumstances; some coals will require a thicker fire than others. The engineer in charge should be the judge as to what thickness is best in order to get the most economical results. At the end of the trial the fire is again to be "hauled" and quenched, the remaining coal weighed up and charged back; the ashes and clinkers to be weighed dry and deducted from the coal charged in order to determine the net combustible. Sometimes it is not practicable to haul the fires in a test, and recourse is then had to the judgment of the engineer or fireman in determining the condition of the fire both at the beginning and end of a trial.

Leaks should be stopped as soon as possible after their discovery, the kind of leak will indicate the treatment necessary. If it occurs around the ends of the tubes it may be stopped by expanding the tubes anew; if in a riveted joint, it should be carefully examined especially along the line of the rivets and care should be exercised in determining whether there is a crack extending from rivet to rivet along the line of the holes; should this prove to be the case, the boiler is then in an extremely dangerous condition and under no circumstances should it be again fired up until suitable repairs have been made which will insure its safety.

Blisters occur in plates which are made up of several thicknesses of iron and which from some cause were not thoroughly welded before the final rolling into plates.

When such a plate comes in contact with the heat of the furnace the thinnest portion of the defective plate "buckles" and forms what is called a blister. As soon as discovered, there should be a thorough examination of the plate and if repairs are needed there should be as little delay as possible in making them. If the blister be very thin and altogether on the surface it may be chipped and dressed around the edges, if the thickness is equal or exceeds one-sixteenth of an inch the blister should be cut out and patched or a new plate put in.

Patching Boilers.—When a boiler requires patching it is better to cut out the defective sheets and rivet in a new one, or if this cannot be done, a new piece large enough to cover the defect in the old sheet may be riveted over the hole from which the defective portion has been cut out. If this occurs in any portion of the boiler subject to the action of the fire, the lap should be the same as the edges of the boiler seams, and should be carefully calked around the edges after riveting. Whenever blisters occur in a plate, patching is a comparatively simple thing as against the repairs of a plate worn by corrosion. In the latter case the defective portions of the plate should be entirely removed and the openings should show sound metal all around, and of full thickness.

If this cannot be obtained within a reasonable sized opening then the whole plate should be removed.

It often occurs that a minor defect is found in a plate and at a time when it is not convenient to stop for repairs; in such an event a "soft patch" is often applied. This consists of a piece of wrought iron carefully fitted to that portion of the boiler plate needing repairs; holes are fitted in both plates and patch and "patch bolts" provided for them. A thick putty consisting of white and red lead with iron borings or filings in them placed evenly over the inner surface of the patch which is then tightly bolted to the boiler plate. This is at best but a temporary makeshift and ought never to be regarded as a permanent repair.

A mistake is often made in making a patch of thicker metal than that of the shell of the boiler needing it. A moments reflection ought to show the absurdity of putting on a five-sixteenth or three-eighths patch on an old one-quarter inch boiler shell; yet it is not so rare an occurence as one would imagine. A piece of new iron three-sixteenths of an inch thick will in most cases be found to be stronger than that portion of a one-quarter inch old plate needing repairs.

CHAP. VI.

BOILER EXPLOSIONS.

There are few facts more difficult to get at than those relating to boiler explosions; and, owing to the absence of reliable data on this subject, the most absurd notions have been advanced as accounting for its disastrous effects under all sorts of conditions from the simple rupture to the true explosion.

Among the causes assigned at one time or another may be mentioned the following:—electricity; decomposition of steam resulting in the generation of explosive gases; overheating of plates; over-pressure; the spheroidal theory, in which a large volume of steam is supposed to be instantly generated by coming in contact with highly heated plates, the water having been previously repelled from the plates by overheating, or by the formation of a vapor between the boiler plate and the water, thereby preventing contact for a time.

As explosions seldom or never give any warning, and are of momentary duration only, it is a very difficult thing to arrive at the true cause of any disaster, and a remarkable thing about it is the evident unwillingness on the part of the owners or those in charge to tell what they do happen to know in regard to the boiler. There is no doubt this has had much to do with surrounding boiler explosions with the air of mystery now so common, and has, no doubt, been a means of perpetuating so many of the absurd theories so common a few years ago, and still believed by many.

Over-pressure.—There is little doubt that the vast majority of boiler explosions can be traced directly to over-pressure. A boiler may be unable to withstand a calculated strain from one of the two following causes, (1) an original defect in the boiler plate, and

(2) by bad workmanship; it is possible, and it actually occurs that these two are sometimes combined in the same boiler; that a boiler containing these two defects should at some time or another meet with disaster is not improbable, but should not be considered as mysterious, or due to occult causes, beyond human knowledge or prevention.

Over-pressure may be sudden or gradual, and when it exceeds its limit of strength the boiler bursts, sometimes with little violence and doing but little damage, in which case it is commonly said to be a simple rupture; at another time the boiler bursts with terrific violence doing great damage and ending in a total wreck of the boiler, it is then said to have exploded. Rupture and explosion seem to be but two names representing in degree the effects following the failure of a boiler.

It is the common practice to permit a pressure per square inch of one-sixth the total strength of the boiler; in all ordinary cases this is an ample margin of safety, but if any one of the plates composing the structure have a hidden and undiscovered defect the boiler may fail in its first trial notwithstanding every care may have been exercised in design and construction.

Defects of this kind rarely occur, the commoner one being that of bad workmanship occasioned by wrong punching, excessive drifting, wrong crossing of seams, over-heating of plates in flanging, grooving with a calking tool, etc. These all tend to lower the strength and safety of the boiler, and it is to be regretted that there are boiler makers who are either so ignorant of proper methods of construction; or so indifferent to the value of life and property that defects of this kind are allowed to pass from them into the hands of an unsuspecting and innocent purchaser. If disaster should follow such a transfer, and the facts could be ascertained, they would at once and completely dispel any fine spun theory of occult causes so far as it related to such a boiler not only, but the aggregation of such testimony would in time place the causes where in most cases they properly belong.

A new boiler ought, if the materials and workmanship are good, and the design suitable for the pressure, such a boiler ought to be safe from bursting up to within a very small margin of the calculated strength.

Experimental boilers have shown the truth of this statement over and over again; yet it would be a hazardous proceeding to raise steam in a boiler which at all approached any such pressure. A single riveted iron boiler 42 inches in diameter, and made of ¼ inch plate having a tensile strength of 45,000 pounds per square inch, may be worked with safety at a pressure of 90 pounds, and ought to bear a pressure of 500 pounds per square inch before rupture. This seems like a very wide margin of safety, but it is none too much.

To show how quickly a boiler will generate steam from a safe to the bursting pressure let us assume that the above boiler contains within it 6000 pounds of water, the grate to have an area of 18 square feet on which are burned 16 pounds of coal per square foot of grate, and each pound of coal to evaporate 8 pounds of water per hour. The ordinary working pressure to be 90 pounds.

The temperature due to a pressure of 500 pounds per square inch is 467° Fahr.; that of 90 pounds pressure is 331° Fahr. Then 467—331=136° difference between the two temperatures.

18 square feet of grate x 16 lbs. coal=288 pounds of coal per hour.

288 lbs. coal x 8 lbs. water=2304 pounds of water evaporated per hour, or 38.4 lbs. per minute.

Then $\frac{6000 \times 136}{38.4 \times 1000}=21\frac{1}{4}$ minutes as the time necessary to burst a boiler by over-pressure under the conditions stated. Now if the strength of the shell should be reduced by bad workmanship, or through any defect in the material, or the thickness reduced by corrosion, or from any other cause so that the shell is reduced to 400 pounds or 300 pounds as the ultimate strength to resist pressure, we see in how short a time it would be possible to generate a steam pressure that would have sufficient power to tear the boiler asunder if once it began to yield and there was no outlet for the steam.

It might be said that the above is not a supposable case, and that such a condition of affairs could not exist in any well regulated establishment. So far from its not being a supposable case there is abundant reason for believing that it not unfairly represents the real reason for a very great number of boiler explosions.

Such a disaster would be likely to occur when the engine was not running and the safety valve was not in good condition.

In order to show how easily it is to be misled into a sense of security through sheer ignorance of facts, and to show that safety valves if not carefully watched and kept in good condition will through neglect become positively dangerous, is abundantly shown in the following figures compiled from four annual reports of Mr. J. M. Allen,* Hartford, Conn., showing that in the regular course of business they discovered in all 1672 defective safety valves of which 678 were regarded as dangerous.

In the great majority of cases the cause of explosion is simply the unfitness of the boiler for the pressure at which it is worked, the unfitness in some instances being due to original malconstruction, and in others to the neglected condition into which the boiler has been allowed to fall; the plates being frequently wasted away by corrosion till reduced to the thickness of ordinary cardboard. Thus boiler owners have it in their own power to prevent by far the greater number of these accidents by simply erecting good boilers instead of low-priced inferior ones, and keeping them in an efficient state of repair.

The notion that there is a mysterious and occult agency at work in the interior of a boiler which may, and sometimes does, liberate itself and thereby produces disastrous boiler explosions is how happily passing away. It is true there have been terrific explosions which have resulted in loss of life and great destruction of property, and which have never been satisfactorily explained, but this by no means strengthens, much less does it prove, any such theory.

There is now little doubt in the minds of those who have made boiler explosions a study, that with few exceptions a good and sufficient reason for the occurance could be furnished not only, but in many cases if not in most of them, the explosion might have been entirely prevented by a careful external and internal examination.

Inspection.—A careful external and internal examination of a boiler is to be commended for many reasons. This should be as

*Pres't Hartford Steam Boiler Inspection and Insurance Co.

frequent as possible and thoroughly done; it should include the boiler not only but all the attachments which affect its working or pressure. Particular attention should be paid to the examination of all braces and stays, safety valve, pressure gauge, water gauges, feed and blow off apparatus, etc.; these latter refer more particularly to constructive details necessary to proper management and safety. The inspection would obviously be incomplete, did it not include an examination into the causes of "wear and tear," and determine the extent to which it had progressed. Among the several causes which directly tend to rendering a boiler unsafe may be mentioned the dangerous results occasioned by the overheating of plates, thus changing the structure of the iron from fine granular or fibrous to coarse crystalline. This may easily be detected by examination, and will in general be found to occur in such cases where the boilers are too small for the work, or fired too hard, or have a considerable accumulation of scale or sediment in contact with the plates. Blistered plates are almost instantly detected at sight, so also is corrosion from whatever cause it may have proceeded.

Corrosion of Boiler Plates.—Iron will corrode rapidly when subjected to the intermittent action of moisture and dryness. Land boilers are less subject to corrosion than marine boilers. The corrosion of a boiler may be either external or internal. External corrosion may in general, be easily prevented by carefully caulking all leaks in the boiler; by preventing the dropping of water on the plates, such for example, as from a leaky joint in the steam pipe or from the safety valve. A leaky roof by allowing a continual or occasional dropping of water on the top of a boiler especially if the boiler is not in constant use, would promote external corrosion. Sometimes external corrosion is caused by the use coal having sulphur in it, and acts in this way: the sulphur passes off from the fire as sulphurous oxide, which often attaches to the sides of the boiler; so long as this is dry no especial mischief is done, but if it comes in contact with a wet plate the sulphurous oxide is converted into sulphuric acid over so much of the surface as the moisture extends, this acid attacks and will in time entirely destroy the boiler plate.

Internal corrosion is not so easily accounted for and is very difficult to correct, especially when it occurs above the water line. It is generally believed to be due to the action of acids in the feed water. Marine boilers are especially subject to internal corrosion when used in connection with surface condensers. A few years ago it was generally supposed to be due to to galvanic action, but that idea is now almost entirely given up From the fact that boilers using distilled water fed into them from surface condensers are more liable to internal corrosion than other boilers has led to the theory that it is the *pure* water that does the mischief, and that a water containing in slight degree a scale forming salt, is to be preferred to water which is absolutely pure.

Whatever may be the truth or falsity of this theory it is a well established fact that distilled water has a most pernicious action on various metals, especially on lead and iron.

This action is attributed to its peculiarly property, as compared with ordinary water, of dissolving free carbonic acid.

One of the worst features in connection with internal corrosion is that its progress cannot be easily traced on account of the boiler being closed while at work. As it does not usually extend over any very great extent of surface the ordinary hydraulic test fails to reveal the locality of corroded spots, the hammer test on the contrary rarely fails to locate them if the plates are much thinned by its action.

Testing Boilers.—It is the general practice to apply the hydraulic test to all new steam boilers at the place of manufacture, and before shipment. The pressure employed in the test is from once and a half, to twice the intended working steam pressure. This test is only valuable in bringing to notice defects which would escape ordinary inspection. It is not to be assumed that it in any way assures good workmanship or material, or good design, or proper proportions; it simply shows that the boiler being tested is able to withstand this pressure without leaking at the joints, or distorting the shell to an injurious degree.

Bad workmanship may often be detected at a glance by an experienced person. The material must be judged by the tensile *strength and ductility* of the sample tested. The design and

proportions are to be judged on constructive grounds, and have little or nothing in common with the hydraulic test.

The great majority of buyers of steam boilers have but little knowledge on the subject of tests, and too often conclude that if they have a certified copy of a record showing that a particular boiler withstood a test of say 150 lbs. that it is a good and safe boiler at 75 to 100 pounds steam pressure. If the boiler is a new one and by a reputable maker that may be true; if it has been in use and put upon the market as a second-hand boiler it may be anything but safe at half the pressure named.

By the hydraulic test, the braces in a boiler may be broken, joints strained so as to make them leak, bolts or pins may be sheared off or so distorted as to be of little or no service in resisting pressure when steam is on.

Hammer Test.—The practice of inspecting boilers by sounding with a hand hammer is in many respects to be commended. It requires some practical experience in order to detect blisters and the wasting of plates, by sound alone. The hammer test is especially applicable to the thorough inspection of old boilers.

It frequently happens in making a test that a blow of the hand hammer will either distort or it be driven entirely through the plate; and it is just here that the superiority of this method of testing over or in connection with the hydraulic test, becomes fully apparent. The writer once knew a locomotive which had been run into the repair shops for some slight repairs, and afterwards was subjected to the usual hydraulic test and was found to be tight, it was then run into the round-house for service, but before it was fired it was accidently discovered by a boy's "fooling" around the fire box with a hand hammer that the plates which were originally five-sixteenths inch thick had been reduced in some places by corrosion to a thickness scarcely more than one-sixteenth inch.

This incident is introduced by way of a digression simply to show the value of the hammer test and the insufficiency of a hydraulic test in the case of boilers which have been for some time in service.

The location of stays, joints, and boiler fittings all modify and

are apt to mislead the inspector if he depends upon sound alone.

There is a certain spring of the hammer and a clear ring indicitive of sound plates which are wanting in plates much corroded or blistered.

The presence of scale on the inside of the boiler has a modifying action on the sound of the plate.

When a supposed defect is discovered a hole should be drilled through the sheet by which its thickness may be determined as well as its condition.

The literature of boiler explosions is by no means scanty and varies anywhere from sound practical experience to the most visionary idealism; but those who have most to do with steam boilers, and whose business it is to trace results to causes, are singularly unanimous in the opinion that almost without exception boiler explosions may be traced directly back to the causes—over-pressure and neglect.

CHAP. VII.

THE SELECTION OF AN ENGINE.

There are so many conflicting statements in regard to the merits and demerits of the several engines placed in the market that one is often confused in judgment, and scarcely knows how to proceed in the matter of selection.

It is easy to advise that, "when you are ready to buy select the best engine, for in the long run the best is the cheapest." No one would pretend to deny this as a general rule, yet there are circumstances which so materially modify this rule that it would seem to a casual observer to be entirely set aside. There are localities in which the price of fuel is so low that it scarcely warrants the doubling of the price on an engine to save it; and in such localities the owners usually want an engine of the very simplest construction, hence, they almost invariably select an ordinary slide valve engine with a throttling governor. This selection is made for several reasons, among which are low first cost, simple in detail, remoteness from the manufacturer or from repair shops.

For small powers in which it is desirable that the investment be as low as consistent with commercial success, the engine selected should be fitted with a common slide valve, this will in general apply to all engines having cylinders eight inches or less in diameter.

If upon a thorough canvass of the situation, it then be thought advisable to employ an automatic cut-off engine, the next question would probably be whether it shall be fitted with a positive, or some one of the various "drop" movements now in the market.

For the smaller sizes, say 8 to 14 inches diameter of cylinder, it will perhaps be found most desirable to use an automatic slide

cut-off, of which there are now several varieties offered through the trade. This style of engine has the advantage of being low-priced, efficient, and economical.

Small engines are usually required to run at moderately high speeds; there is a very decided advantage in this on the score of economy, as a small engine running at a quick speed will be quite as efficient as a large engine running at a slow speed, with the further advantage that the former will not cost in original outlay more than about two-thirds of the latter, while the cost of operating will be no greater per indicated horse power.

Large slide valves have not been found to work satisfactorily for any great length of time, and especially in quick moving engines. They are still used in marine engines notwithstanding the objections urged against them, for the reason that no equally efficient substitute is available.

The slide valve is still used to the almost total exclusion of all other kinds in locomotives. It is doubtful whether a better valve for that particular use can be devised. It is simple, efficient, and readily obeys the action of the link when controlled or adjusted by the engineer. For portable engines and the smaller stationary engines it leaves little to be desired in point of simplicity.

One objection to a slide valve is that it cannot readily be made to cut off steam at say half-stroke or less without interfering with the exhaust. In ordinary practice $\frac{5}{8}$ to $\frac{2}{3}$ seems to be where most slide valves cut off as a minimum, perhaps $\frac{3}{4}$ would represent nearer the actual average conditions.

It can easily be shown that this is very wasteful of steam and consequently not economical in fuel; but as there are cases in which the loss in fuel is fully gained by other advantages, the ordinary slide valve will, in all probability, continue to be used.

Balancing Slide Valves.—For very large valves, such as those employed in marine engines, some attachment for relieving the pressure on the valve face seems almost imperative. This is usually accomplished by having an adjustable ring fitted to the back of the valve by which an equilibrium is established between the valve face and the area of the ring opposite, and which very *nearly balances* the whole valve.

There have been many attempts at balancing the ordinary stationary engine valves, but with only partial success. Almost any of the devices offered for this purpose work satisfactorily so long as they are new, but they presently become inoperative, if not troublesome.

That some devices should work well longer than others is to be expected; but on the whole it is doubtful whether there are any of the so-called balanced valves which work satisfactorily after a year's constant service without repair and adjustment.

The writer has tried several valves of this class and found that three months' constant wear without attention or adjustment was the average duration of their practical usefulness. There is a method of balancing semetimes used, which consists of a "bridge" over the valve and through which the valve slides; this "bridge" taking off the pressure from the back of the valve, but in no manner interfering with its action, nor is there any liability for a steam leak through the back of the valve into the exhaust port.

The pressure on the back of a valve may be considerable, but just how much power is absorbed in overcoming the resistance due to the steam pressure throughout the entire travel of the valve cannot be easily determined except by direct experiment with the valve of an engine actually at work. There is no doubt that the power lost in overcoming this resistance has been greatly overestimated, and many devices have been brought out through an imperfect knowledge of the actual loss occasioned by the use of an unbalanced valve, and disappointment has often been the only reward gained by the inventor and experimenter, who had been lead into the belief that at least 25 per cent. of fuel was to be saved by balancing the slide valve.

The Horizontal Engine commends itself on account of its compactness, the facility with which it may be secured to its foundation and the accessibility of its several parts.

Whether the engine shall have what is known as a box bed, or a girder bed, or whether the cylinder shall be overhanging or not will depend upon circumstances, this subject is in general, simply a matter of opinion or personal preference, and has little to do with the actual performance.

Vertical Engines occupy but little ground space and are in favor among engineers, especially for small powers; but this style of engine is by no means confined to small powers as it is now and has long been a favorite one for marine engines.

It is also a favorite design for blowing engines, and notwithstanding the objections against it, is likely to occupy a permanent place in engine design.

Beam Engines are, when viewed from the commercial standpoint, suitable only for very large powers. This is a very expensive form of engine to construct, and hence should always be fitted with the highest class of automatic cut-off mechanism, except when it is to be employed as a pumping or blowing engine, in which case the valve mechanism will, of course, be adapted for the service required.

The great number of parts and joints required in a beam engine, especially when fitted with parallel motion rods, and the excessive weight of the completed engine place it at a great disadvantage when brought in competition with its more compact, simpler and lighter rival,—the horizontal engine.

A great deal can be said in favor of a beam engine when it requires to be of large size. The piston and connections attached to the one end of the beam may be exactly balanced by the connecting rod and pumps on the other side, in which case the combined weight of the beam and connections will be concentrated in the center bearings supporting the beam; this it may be said applies only to the engine at rest; when in motion the forces are differently distributed, for example—when the piston is ascending there is a tendency to lift the beam from its center at the beginning and during the continuance of the stroke, this tendency is reversed during the downward movement, in either case all the strains are transmitted directly to the foundations.

A cast-iron cylinder of large dimensions has a tendency to flatten or to become oval when laid down on its side. This makes fitting a piston steam tight a very difficult operation unless some provision be made for keeping it round; in this respect a vertical *cylinder has* a very decided advantage, for it can be bored while

in a vertical position and thus insure its being perfectly cylindrical when fixed to the bed plate.

High Speed Engines.—The general tendency seems now to be in the direction of a horizontal engine with a stroke of medium length, having a rapid piston speed, and a rapid rotation of crank shaft, rather than a longer stroke with a less rate of revolution. This rapid movement of piston and crank shaft permits the use of small fly wheels and driving pulleys, and thus very materially reduces the cost of an engine for a given power.

To illustrate this, it may be said that a 16 x 48 inch engine using steam at 80 pounds pressure and cutting off ¼ stroke, running at the rate of 60 revolutions per minute, may be replaced by an engine having a 13 x 24 inch cylinder, running at the rate of 200 strokes per minute, the pressure of steam and point of cutting off remaining the same, both engines being non-condensing, and representing the best examples of their kind. The difference between 60 and 200 revolutions per minute in millwright work is very great, but there is a constantly growing demand for an engine which shall meet such a requirement whenever it shall present itself; by this is not to be understood an engine which shall be used at either speed indiscriminately, but rather a type of engine which shall be economical in fuel, and shall be of a kind by which the rate of revolution may be such as to suit the millwrights work without loss of economy in working, and without excessive outlay for the engine itself in proportion to power developed.

Slow speed engines are designed and built from a standpoint entirely different from that of high speed engines; in the former case the reciprocating parts are made as light as possible consistent with safety. The fly wheel is large in diameter and made with a very heavy rim, especially is this the case with automatic cut-off engines of long stroke and slow revolution of crank shaft.

In high speed engines the reciprocating parts are often of great weight in order to insure the utmost smoothness of running. The piston and cross-head are made of unusual weight that at the beginning of the stroke they may require a large part of the steam pressure to set them in motion, this absorbing of power at the beginning of the stroke is for the purpose of temporarily storing it

up in the reciprocating parts that it may be given off at the later portions of the stroke by imparting their momentum to the crank; thus at the beginning of the stroke these reciprocating parts act as a temporary resistence, but once in motion they tend by their inertia to equalize the pressure on the crank pin, and so produce not only smooth running, but a very uniform motion.

Results to be obtained in practice.—The best automatic non-condensing engines furnish an indicated horse power for about three pounds of good coal depending somewhat upon the fitness of the engine for the work and the quality of the coal. With a condenser attached a consumption as low as two pounds has been reported, but this is an exceptional result, 2½ pounds may be quoted as good practice. The larger the engine the better the showing as compared with smaller engines.

For ordinary slide valve engines the coal burned per indicated horse-power will vary from 9 to 12 pounds, for the sake of illustration we will say 10 pounds, and that the engine is of such size as would require for a years run, $3,000 worth of coal, now an ordinary adjustable cut-off engine with throttling governor ought to save at least half that amount of coal or say $1500 per year; if the best automatic engine were employed using 2½ pounds of coal per horse power, a further saving of $750 per year could be effected, or between the two extremes $2250 per year in saving of coal without interfering in any way with the power, with the exception perhaps that the automatic engine will furnish a better power than the former engine. It is easy to see that, it is true economy to buy the best engine and pay the extra cost of construction if the saving of fuel is an element entering into the question of selection.

The cost of an engine for any particular service is always to be taken into consideration, for it is possible to contract for a certain saving of coal at too high a price, not simply when paid out as the original purchase money, but with this economy of fuel the purchaser may have many vexatious and damaging delays caused by the breaking of the automatic mechanism of the engine. All *such delays* which would not have occurred to an ordinary or *simpler engine, are to* be charged against any saving credited to

the engine which failed in producing a regular and constant power. Take a flouring mill for example, producing 400 barrels per day, it is easy to see how a single days stoppage would interfere with the trade and shipment by the proprietors, yet it would require a very small break in an engine that would require less than a day for repairs.

This does not argue against high grade engines, but the purchaser should be certain that the engine when once on its foundations shall be as free from dangers of this kind as any other engine of similar economy.

There are engines which from their peculiar construction appear to be very complex and this objection is often urged against them, while the fact is the complexity is apparent rather than real. Take the Corliss engine for example, it is doubtful whether there is another automatic cut-off engine in successful use in this or any other country which has cost less for repairs during the last ten or twenty years. It is true it contains a great many separate pieces in the valve mechanism, but the pieces themselves are simple, durable, easily accessable, and always in sight. These several parts are not liable to excessive wear, but such as there is can be readily adjusted.

The engines to be preferred are those in which the valve adjusting mechanism is outside of the steam chest and which is in plain sight at all times when the engine is in motion.

Location of Engine.—This will depend upon circumstances, but it is far from true economy to place an engine in a dark cellar or in some inconvenient place above ground. The engine as the prime mover should have all the care and attention which may be needed to insure regular and efficient working.

Machinery in the dark is almost sure to be neglected. If the design of the building or the nature of the business is such that the engine must be located underground there should be some provision for letting in the daylight, the extra expense incurred will soon be saved by the order, cleanliness. and fewer repairs required, following neglect.

The engine should always be close to, but not in the boiler room.

Many a high-priced engine has had its days of usefulness shortened by the abrasive action of fine ashes and coal dust coming in contact with the wearing surfaces. There should always be a wall or tight partition between the engine and fire room.

The foundations for an engine should be large and deep. Too many manufacturers in marking dimensions on foundation drawings for engines, make them altogether too shallow. The stability of an engine depends more on the depth than on the breadth of the foundations. Stone should be used for foundations rather than brick, but if the latter must be used they should be hard burned and laid in a good cement rather than a lime mortar. If the bottom of the pit dug for the engine foundation be wet, or the soil uncertain in its stability, it is a good plan to make a solid concrete block about a foot and a half thick, on which the foundation may be continued to the top. If such a concrete block be made with the right kind of cement it will be almost as hard and solid as a whole stone.

The most economical engine is the one in which high pressure steam can be used during such portion of the stroke as may be necessary, then quickly cut off by a valve which shall not interfere with the exhaust at the opposite end of the cylinder, and allow the steam to expand in the cylinder to a pressure which shall not fall below that necessary to overcome the back pressure on the piston. In general, the most successful cut-off engines use the boiler pressure for a distance of one-fifth to three-eighths of the stroke from the beginning, at this point the steam is cut off and allowed to expand throughout the balance of the stroke.

The gain by expansion consists in the admission of steam at a pressure much above the average required to do the work, and allowing it to follow but a small portion of the stroke then expanding to a lower than the average pressure at the end of the stroke. The mean effective pressure on the piston is that by which the power of the engine is measured, hence it follows that the higher economy is to be reached, other things being equal, where the mean effective pressure on the piston is highest when compared *with the* terminal pressure, or the pressure at the end of the

stroke. In order to get this, a high initial pressure is used; the steam follows as short a distance as possible to keep the motion regular under a load, and then expanding down to as near the atmospheric pressure as possible.

The following table exhibits at a glance the performance of a non-condensing engine cutting off at different portions of the stroke. The initial pressure of steam being in each case 80 pounds per square inch.

	CUT-OFF IN PARTS OF THE STROKE.				
	$\frac{1}{10}$	$\frac{2}{10}$	$\frac{3}{10}$	$\frac{4}{10}$	$\frac{5}{10}$
Mean effective pressure,	18	35	48	57	65
Terminal pressure.	11	20	30	39	48
Pounds water per h'r per H. P.	20	21	22	23	25

Fractions are omitted in the above table and the nearest whole number given.

In general, it may be said the higher the rate of expansion, the greater the economy, but there are modifying influences which are to be taken into account.

If expansion be carried to an extreme degree the engine will require to be much larger than if the expansion were less, to get the same indicated horse power. In making a larger cylinder the whole engine would require to be larger and the cost would be much greater also. Builders of automatic cut-off engines are now pretty well agreed on recommending an engine which shall use steam from 75 to 80 pounds and follow one-fourth of the stroke.

An efficient steam jacket will add to the economy of the engine especially if the cylinder is long stroke and the revolutions of the crank slow. This has already been referred to in another chapter, see page 19.

The objection to using a high initial pressure of steam following but a short distance, and expanding to a low terminal pressure is, for single cylinder engines, the very great variation in the strain brought upon the moving mechanism, and especial

on the crank-pin; it also necessitates a larger cylinder, and greater strength in the framing as well as the moving parts of the engine.

Condensation of Steam.—In order to attain the highest economy in a steam engine a condenser should be attached, especially if the cylinder be of large diameter and the average or terminal pressure be low.

Condensers.—The earliest forms of the steam engine made use of the cylinder of the engine as a chamber for the condensing of the steam; this was, of course, a great mistake, and operated against its economy. By using a separate vessel for condensation it is said that Watt doubled the power of the engine, and since his day it has been the universal practice to so construct engines and condensers.

Without being exact, it requires about twenty-five times as much water to successfully operate a jet condensor as that evaporated in the boilers in the generation of steam to supply the engine.

So long as there are no leaky joints between the engine cylinder and the condenser it matters little what may be the distance between them, still, it is on the whole, better to have them close together. It is necessary to exclude air from the condenser at all times because it interferes with the formation and maintainance of a vacuum, and it is for this reason that unnecessary joints between the cylinder and the condenser are to be avoided.

The injection pipes should be large, and as free from abrupt turns as possible. In regulating the supply of water to the condenser, a cock is to be preferred to an ordinary globe valve.

The condensing chamber may be from one-third to one-half the area of the cylinder, and in regard to design, it may be that which seems best suited to the local conditions likely to affect it; such for example, as being located below the engine room floor, or in a basement removed from the engine room, or perhaps on the same floor with the engine; these will have more or less influence in determining the special form it shall have.

The object of a condenser attached to an engine is to reduce the *back pressure*, or that pressure opposed to the movement of the

piston when driven by the steam flowing into the cylinder from the boiler.

Condensers are rarely attached to other engines than those fitted with a cut-off; the expansion of steam in the cylinder could not in an ordinary non-condensing engine be reduced to a point much below five pounds per square inch above the atmosphere, but with a condenser it may be carried to twelve or thirteen pounds below it. It is apparent, therefore, that the gain by the use of a condenser, especially in connection with pistons of large area, is very considerable.

The condenser should be kept at as low a temperature as possible, but this should not be brought about by overloading the air pump with water. It is better to lose a pound or two of vacuum than impose upon the engine the extra work required to expel perhaps twice as much injection water as may otherwise be necessary to give a fair vacuum. The temperature of the hot well is perhaps the best guide for the engineer, which during the summer months may be about 120° Fahr.; in the winter months it may be lower, but just how much will suggest itself to the careful engineer who will adjust the supply so that a good vacuum may be maintained with the least load upon the engine.

The two limits to the temperature of the hot well of the condenser are, (1) the boiling point of water in a vacuum and (2) the overloading of the air pump. In regard to the lead upon the latter the engineer must determine this for himself by the working of the engine.

A good jet condenser ought to yield a vacuum of 26 inches (13 pounds) at all times. Sometimes this may be exceeded, but in general it is regarded as good practice.

The less injection used the hotter will be the escaping water, but in no case ought it to greatly exceed 120°, and when it can economically be brought below this it ought to be done. If the feed water for the boiler is taken direct from the hot well it will be found more economical to heat it on its way to the boiler by passing it through the escaping gases from the furnace than to increase the temperature of the condenser.

Air Pumps may be arranged to be either single or doubl

acting; perhaps most of them are single acting, in which case the capacity may be one-fifth that of the cylinder.

Double acting pumps should be about one-eighth the capacity of the cylinder; a very common practice is to make them, when not driven directly from the piston of the engine, one-half the diameter and one-half the stroke of the engine.

Surface Condensers are not often used in connection with stationery engines. The few that are in use are confined mainly to the sea coast, or such other localities as cannot furnish water sufficiently pure for the economical generation of steam. The process of surface condensation consists in having a large receiving vessel into which the steam from the engine is exhausted, this vessel usually has an outer and inner chamber, the latter being fitted with as many small brass or copper tubes as it will contain; these tubes are generally $\frac{5}{8}$ inch in diameter. The usual practice is to exhaust the steam in the outer chamber and outside of the tubes and force a current of cold water through the tubes; in this way the heat is absorbed from the steam by contact with the cold metallic surface presented by the tubes, and which is maintained at a low temperature by the flow of cold water through them.

The object sought by this device is to condense the steam furnished by the boilers after its use in the engine, and return it again to the boilers, and so use the same water over and over again. This pure feed water is intended to prevent the formation of scale in steam boilers and thus secure an economy of fuel not easily attained by other methods.

Steamships are now rarely fitted with other than surface condensers, and although very great benefit has been derived by the use of a surface over a jet condenser it has brought with it evils of a very serious nature, the principal one being a certain corrosive action that has been found to attack the internal surfaces of iron boilers using condensed water.

There has been so far no satisfactory explanation for this corrosive action; among other theories in regard to it is that certain fatty matter used in lubricating the valves and piston is carried over with the exhaust steam and so passes into the boiler with the feed water; it is there decomposed and acts on the iron as a

chemical solvent. The correctness of this theory has never been proven, and is gradually losing ground.

Galvanic action has also been suggested as accounting for the corrosion though it has now but few adherents.

The cause of this singular and rapid corrosion of steam boilers when used in connection with surface condensers is not thoroughly understood.

Governor.—Any automatic device by which the speed of an engine is controlled may properly be called a governor. There are now two distinct methods by which the steam supplied to an engine is thus brought under control. The first is usually applied to slide valve engines having a fixed cut-off, and consists in the adjustment of a valve by which the *pressure* of steam in the cylinder is increased or diminished in order to maintain a constant rate of revolution with a variable load. The second device consists in a mechanism by which the whole boiler pressure is admitted to the cylinder which is allowed to follow the piston to such portion of the stroke as will maintain a regular rate of revolution; the steam is then suddenly cut off at each half revolution of the engine and thus furnishing a greater or less *volume* of steam at a constant pressure.

Neither of these two varieties of governors will act until a change in the rate of revolution of the engine occurs, and this change will either admit more or less steam as it is faster or slower than that for which the governor is adjusted.

The commonest form of a governor consists of a vertical shaft to which are hinged two arms containing at their lower ends a ball of cast iron; as the shaft revolves the balls are carried outward by the action of what is commonly called centrifugal force, the greater the rate of revolution the further will the balls be carried outward, advantage is taken of this property to regulate the admission of steam to the engine.

The action of the balls and that of the valve include two distinct principles and should be considered separately; an excellent valve may be manipulated by an indifferent governor and so produce unsatisfactory results; on the other hand, the governor mechanism may be satisfactory in its operation, but being con-

nected with a valve not properly balanced, is likely to cause a variable rate of revolution in the engine.

The writer is somewhat acquainted with the history of the growth of several governors now in good repute, and it seems to be inseparable from their final completion, that a long and vexatious period of practical experimenting with each size shall intervene between the original design and a reliable marketable product. This has had the effect to concentrate the manufacture of governors in the hands of a few persons who by the aid of special machines and careful adjustment of details to requirements have produced governors which are not surpassed in any country.

Fly-Wheel.—The object in attaching a fly-wheel to an engine is to act as a moderator of speed. The action of the steam in the cylinder is variable throughout the stroke, against which the revolution of a heavy wheel acts as a constant resistance, and limits the variations in speed by absorbing the surplus power of the first portion of the stroke, and giving it out during the latter portion. The fly-wheel is simply a reservoir of power, it neither creates nor destroys it, and the only reason why it is attached to an engine is simply to regulate the speed between certain permitted variations which are necessary to cause the governor to act, and to equalize the rate of revolution for all portions of the stroke, thus converting a variable reciprocating power into a constant rotary one.

It is considered good practice to make the diameter of the fly-wheel four times the length of the stroke for ordinary engines, in which the stroke is equal to twice the diameter of the cylinder. This may be taken as a fair proportion in engine building, and furnishes a wheel sufficiently large to equalize the strain, and reduce any variation in speed to within very narrow limits if the engine is supplied with a proper governor.

The greater the number of revolutions at which the engine runs the smaller in diameter may be the fly-wheel, and it may also be largely reduced in weight for engines developing the same power.

Horse-Power.—By this term is meant 33,000 pounds raised one

foot high in one minute. The horse power of an engine may be found by multiplying the area of the piston in square inches, by the average pressure throughout the stroke, this will give the total pressure on the piston; multiply this total pressure by the length of the stroke of the piston in feet, this will give the work done in one stroke of the piston; multiply this product by the number of strokes the piston makes per minute, which will give the total work done by the steam in one minute; to get the horse power divide this last product by 33,000.

From this deduct say 20 per cent. for various losses, such as friction, condensation, leakage, etc.

CHAP. VIII.

CARE AND MANAGEMENT OF A STEAM ENGINE.

It is to be supposed to begin with that the engine is correctly designed and well made, and that after a suitable selection of an engine, for the work to be done nothing now remains except a proper care and management.

Lubrication.—The first and all important thing in regard to keeping an engine in good working order is to see that it is properly lubricated. This does not imply, neither is it intended to encourage the use of oil to excess; all that is needed is simply a film of oil between the wearing surfaces. It is marvelous how small a quantity of oil is required when of good quality and continuously applied. There are several self-feeding lubricators in the market which have been tested for years and are a pronounced success; these include crank-pin oilers in which the oscillatory motion of the oil makes a very efficient self feeding device, the flow being regulated by means of an adjustable opening to the crank-pin, or in the adjustment of a valve by which its lift is regulated by each throw of the crank; and in others by a continual flow through a suitable tube containing a wick or other porous substance. For stationary engines it is desirable that the main body of the oiler be made of glass that the flow of oil may be closely watched and adjusted accordingly.

For the reciprocating and rotary parts of the engine, a modification of the above mentioned oilers may be used. They are of various patterns and devices and many of them very good. It is also a good plan to have some device by which the cross-head at *each end* of each stroke will take up and carry with it a certain

amount of oil; for the lower half of the slide this is not difficult to arrange, for the upper side an automatic feeder placed in the middle of the slides will provide ample lubrication.

For oiling the main bearing there should be two separate devices, one an automatic glass oiler, and in addition, a large tallow cup attached to the cap of the bearing. This cup should be filled with tallow mixed with powdered plumbago; the openings from the bottom of the cup to the shaft should be not less than quarter-inch for small engines, and three-eighths to half-inch for larger ones; so long as the main bearing runs cool the tallow will remain in the cap unmelted, but if heating begins the tallow will melt and run down on the surface of the revolving shaft and thus provide an efficient remedy when needed.

For oiling the valves and piston a self-feeding lubricator should be attached to the steam pipe, this by a continuous flow of oil will be found not only satisfactory in its practical working but economical in the use of oil.

In selecting an oil for an engine it is in general better to use a mineral rather than an animal oil, especially for use in the valve chest and cylinder. The objection to an animal oil, and especially to tallow or suet is that it decomposes by the action of the heat, often coating the surface of the steam chest, the piston ends and the cylinder heads with a deposit of hard fatty matter, or forms into small balls not unlike shoemaker's wax. There is no such decomposition and formation in connection with mineral oils which may now be had of uniform quality and consistency, and at much lower prices than animal oils.

The Slide Valve should be kept properly set and should be examined occasionally to see that the face and seat are in good condition. So long as this is the case, the valve mechanism and the valve itself must be let alone, and not tampered with. It is a part of the manufacturers business to set the valve and properly fit and adjust the valve connections before the engine leaves the shop; the eccentric should then be keyed to the shaft and not held by a set screw, as the latter is likely to work loose and make lots of trouble. If the eccentric is keyed to the shaft the only adjustment necessary in the valve connection is to take up the

wear of the joints, this is easily done and will not require doing oftener than once or twice a year, depending on the care the engine receives.

Should the eccentric be fastened by means of a set screw instead of a key, and it should work loose after running for some time, it may easily be brought back to the original position by taking off the steam chest cover and after placing the engine on a dead center, move the eccentric around the shaft until the valve is just about to open the port; care being taken that the center line of the eccentric "leads" the crank-pin in the direction in which the engine is to run if the connections are so made, if not, then the eccentric must be moved around on the opposite side of the shaft. When this adjustment is made, secure the eccentric by tightening the set screw; then turn the engine over to the other dead center and ascertain how near the valve is open on that side; whatever difference there may be can easily be adjusted by means of the nuts on either side of the valve or at the eccentric if the adjustment is to be made there.

After equalizing the opening of the valve for the two dead centers the eccentric is to be permanently fixed to the shaft. A mark should be affixed to both the eccentric and the shaft when in proper position, so that in the event of any future slippage it may be brought back to the same place without having to re-set the valve. When a key is used instead of a set screw, such a thing as slippage of the eccenteic becomes impossible, and an engine cannot be said to be completed until that is done.

Lead is the amount of opening which a valve has when it is just beginning the stroke.

It is not now customary to give engines lead except in special instances when it is found to be absolutely necessary. The exhaust side of the valve is so proportioned that the "exhaust" or the steam remaining in the cylinder is cushioned up to pressure at the beginning of the next stroke. It is claimed that it effects a greater saving of steam than if there were no cushion and the valve had lead. Exact data are wanting on this point, but so far the prevailing opinion and practice is in favor of cushioning.

The Piston Packing will need looking after occasionally to see that it does not gum up and stick fast, which it is very likely to do when the cylinder is lubricated with tallow or animal oil.

The rings should fit the cylinder loosely and should be under as little tension as possible and insure perfect contact. If the rings are set out too tight they are liable to scratch or cut the cylinder; if too loose the steam will blow through from one end of the cylinder, past the piston, and into the other. In adjusting the springs in the piston care must be exercised that the adjustments are such as will keep the piston rod exactly central, to prevent springing the rod or causing excessive wear on the stuffing box.

There are several packings which do not require this adjustment, the rings being narrow and either expanding by their own tension or by means of springs underneath. The only thing to be done with such a packing is to keep it clean, and when lubricated with a mineral oil this is not a difficult matter.

Steam packages are also largely used, their use has not become so general as spring packings, though in some localities they are extensively used, such a packing possesses several good talking points. With this style of packing the only thing required is to see that it is kept clean, and the openings free for the admission of the steam.

The Stuffing Boxes whether for the piston or valve stems need to be looked after carefully, and to prevent leaking will require tightening from time to time. There are several kinds of ready-made packings in the market containing rubber, canvas, soap-stone, asbestos and other substances which form the basis of a good durable packing. These can be had in sizes suitable for all ordinary purposes, and their use is recommended.

In the absence of any of these, a packing made of clean manilla or hemp fibre will serve a useful purpose. Formerly it was the only substance used, but is being gradually superceded by the other kinds mentioned above.

In packing the small and delicate parts such as a governor stem, a good packing is made by plaiting together three or more strands of cotton candle-wick. This is soft, pliable, free from anything

like grit, and will not get hard until soaked with grease and baked into a brittle fibreless substance not easily described.

Crank-Pins.—There are few things more troublesome to an engineer than a hot crank-pin, and it is sometimes very difficult to get at the real reason why it heats. Among the principal reasons for heating are: the main shaft is not "square" with the engine, or, that the pin is not properly fitted to the crank, or perhaps it is too small in diameter, defects which are to be remedied as soon as practicable. Heating is often caused by the boxes being keyed too tightly, or by insufficient lubrication.

There are now several good self-feeding lubricators in the market which will supply the oil to a crank-pin continuously, these are recommended rather than the old style of oil cup which was not only uncertain but doubtful in its action. Many troublesome crank-pins have been cured of heating by this simple matter of constant lubrication.

When the crank-pin is rather small for the engine, and the load variable, there is a possibility of having a hot pin at any time; it is advisable to have ready some simple and effective expedient to be applied when it does occur; for this there is perhaps nothing better and safer than a mixture of good lard oil and sulphur.

Connecting Rod Brasses.—In quick running engines the brasses should be fitted metal to metal, or if this is not desirable, several strips of tin or sheet brass should be inserted between them and then keyed up tight. This gives a rigidity to a joint which is difficult to secure when the brasses have a certain amount of play in the strap.

It is a common practice to bore the brasses slightly larger than the pin, so that when fitted to it the hole shall be slightly oval and thus permit a freer lubrication than is secured by a close fit around the whole circumference.

Knocking.—There are several causes which, combined or singly, tend to produce knocking in steam engines.

In most cases the difficulty will be found to be in the connecting rod brasses, but whether in the crank-pin end, or at the cross-head

is not easily determined in all cases. A very slight motion will often produce a very disagreeable noise, the remedy is in most cases very simple, and consists in simply tightening the brasses by means of the key or other device that may have been provided for their adjustment. In adjusting a key it is the common practice to drive it down as far as it will go, marking with a knife blade the upper edge of the strap, then drive the key back until it is loose, after which drive it down again until the line scratched on the key is within $\frac{1}{4}$ or $\frac{1}{8}$ of an inch of the top of the strap. The size of the strap joint, and the judgment of the person in charge must decide the best distance. This may be done at both ends of the connecting rod. On starting the engine, the cross-head and crank-pins must be carefully watched, and upon the slightest indication of heating, the engine should be stopped and the key driven back a little further. A slight warmth is not particularly objectionable, and will as a general thing correct itself after a short run.

Knocking is sometimes occasioned by a misfit either in the piston or the cross-head, and the piston-rod. These connections should be carefully examined, and under no circumstances should lost motion be permitted at either end of the piston-rod.

If the means of securing are such that the person in charge can properly fasten the piston to the rod, he should see that it is kept tight, if not, then it should be sent to the repair shop at once, as there is no telling when an accident is likely to overtake an engine with a loose piston.

The connection between the piston-rod and cross-head is usually fitted with a key and furnishes a ready means of tightening the joint, if proper allowance has been made for the draft of the key. In case there has not, the piston-rod and cross-head should be filed out so that the draft of the key will insure a good tight joint when driven down.

The main bearing should be examined and if there should be too much lateral movement of the shaft, the side brasses should then be adjusted until the shaft turns free, but has no motion other than a rotary one. The cap to the main bearing should also be carefully examined, as it may need screwing down and thus

prevent an upward movement of the shaft at each stroke, this applies more particularly to quick running engines.

Engines which have been in use for some time are likely to have a knock caused by the piston striking the head. This is brought about by having a very small clearance in the cylinder and in not providing by suitable liners for the wear of the connecting rod brasses.

In a case of this kind, liners should be inserted behind the brasses in the connecting rod, or new brasses put in which will restore the piston to its original position.

Knocking may be caused by defects in the construction of the engine, such for example as not being in line, the crank-pin not at right angles to the crank, the shaft may be out of line, etc.

Whenever the cause is one in which it can be shown that it is a constructive defect, there is but one remedy, and that is the replacing of that part, or the assembling of the whole until perfect truth is had in alignment of all the parts.

This may or may not require the services of an expert, but all improperly fitting pieces should be replaced by new ones, as a safe-guard against accident which is likely sooner or later to overtake badly fitting pieces.

If the boiler is furnishing wet steam or priming so as to force water into the steam pipe it will collect in the cylinder and will not only cause knocking, but on account of its being practically incompressible there is danger of knocking out a cylinder-head, bending the piston-rod, or doing other damage to the engine. The cylinder cocks should be opened to drain any collected water away from the cylinder.

Steam Jackets.—In order to secure the advantage of steam-jacketing it is not sufficient to merely place around the cylinder a casing which *may* contain steam; care must be taken that this jacket always *does* contain steam.

In other words, means must be provided for keeping the jacket clear of water and air.

Too many jackets are "steam" jackets only in name, and hence the contradictory testimony which has arisen regarding their action. Few but those who have actually tried it, fully appreciate

how soon a jacket may be rendered ineffective by the accumulation of air and water.

Repairs.—Whenever it is necessary to make repairs the work should be done at once, oftentimes a single days delay will increase the extent and cost four-fold. If an engine is properly designed and built the repairs required ought to be very trivial for the first few years it is run if it has had proper care. It may be said in reply to this "true, but accidents will happen in spite of every care and precaution." That accidents do occur is true enough, that they occur in spite of every care and precaution is not true. In almost every case accidents may be traced directly back to either a want of care, negligence, or to a mistake.

Fitting Side-Valves.—The practice of fitting a slide-valve to its seat by grinding both together with oil and emery is wrong and should never be resorted to. The proper way to fit the surfaces is by scraping, this insures a more accurate bearing to begin with, and will also be entirely free from the fine grains of emery which find their way and become imbeded in the pores of the casting and are thus liable to cut the valve face and destroy its accuracy. The scraping of the valve and seat has a beneficial effect by causing the removal of the fine particles of iron which are loosened by the action of the cutting tool in the planing machine, and which ought to be fully removed before the engine leaves the manufacturers hands.

Aside from this it is doubtful whether the scraping amounts to anything practically, for the reason that the cylinder and valve are fitted cold and their relative positions are distorted by the action of the heat of the steam, once the engine is in use. The scraping which simply renders the valve face and seat smooth and hard is all that is sufficient to begin with, and may be re-scraped after the valve has been in use a few days, should it be found necessary; which will not often be the case in small and ordinary sized engines.

Eccentric Straps are likely to need repairs as soon as anything about an engine. They should be carefully watched at all times.

If they are likely to run hot, it is also probable there is more or less abrasion or cutting going on, if so, and prompt measures are not taken to arrest it, they are likely to cut fast to the eccentric and a breakage is sure to occur.

When the straps begin to heat, the bolts should be slackened a little and at night or perhaps at noon, the straps should be taken off and all cuttings carefully removed with a scraper, (not with a file) the rough surfaces on the eccentric should be removed in the same manner.

The straps should be run loose for a few days, gradually tightening as a good wearing surface is obtained.

The Main Bearing, if neglected, is a very troublesome journal to keep in order. The repairs generally needed are those which attend overheating and cutting. The shaft, whenever possible, should be lifted out of the bearing and both the shaft, bottom of main bearing and side boxes carefully scraped and made perfectly smooth. It sometimes occurs that small beads of metal project above the surface of the shaft which are often so hard that neither a scraper nor file will remove them, chipping is then resorted to and the fitting completed with a file and fine emery cloth.

Governor.—It not infrequently occurs that after an ordinary throttling engine has been used a few years, that the speed becomes variable to such a degree that it interferes with the proper running of the machinery. This occurrence can generally be traced directly to the governor. When it does occur the governor should be taken apart and thoroughly examined; if the needed repairs are such as can easily be made in an ordinary repair shop they should be made at once, if not, a new governor should be purchased. The price of governors is now so low that it is better and more economical to buy a new one than lose the time and pay the bills for repairing an old one.

Automatic Engines.—In the care and management of this class of engines it is difficult to say just what particular attention they need, owing to the variety of styles and the peculiarities of each.

As a rule, however, they require first, to be kept well oiled; second, to be kept clean; third, to be kept well packed; and fourth, to be let alone nights and Sundays.

There is little doubt that there has been more direct loss resulting from a ceaseless tinkering with an engine than results from the legitimate wear and tear to which the engine is subjected. The writer does not wish to be understood as saying that builders of this class of engines are infallible; it might be diffiult to prove any such assertion in case it was made, but it may be said with truth that the engines of this class now in the market are carefully designed, well proportioned, of good materials and workmanship, and as examples of mechanism are entitled to take very high rank.

The writer knows of several engines of this class which have not cost their owners for repairs so much as five dollars in five years' constant use.

A manufacturer writes thus, to to the builder of his engine: "The engine which you furnished us (16 x 30) has been in constant use for more than four years, running at 132 revolutions per minute, sometimes as auxiliary to water power and sometimes at its full power. It has cost us nothing for repairs."

It is essential to the economical working of these engines that the cut-off mechanism be in good order and properly adjusted. Whenever the valves need re-setting the final adjustments should be made with a load on the engine, and with the indicator attached to the cylinder, the valves being set by the card rather than by the eye. No general rule can be given for setting the valves as the practice varies with the size and speed of the engine, nor is any rule needed, for the indicator will furnish all the data required. The adjustments may then be made so as to secure prompt admission, sharp cut-off, prompt release, and the proper compression.

CHAP. IX.

PORTABLE ENGINES.

In the preparation of this chapter it was thought best to combine the subjects of selection and management in the same article instead of separating them as in the preceding chapters. This necessitated in some cases a repetition of what had already been expressed. One of the principal objects in writing this book was to furnish farmers and others who have occasion to use portable engines a practical guide to assist them in care and management.

Selection.—In the selection of a portable engine preference should be given the one which combines in the highest degree:—good proportions, simplicity of detail, compactness, strength, lightness, good workmanship, interchangeability of parts, and affording the readiest facility for examination, cleaning and repairs.

Efficiency and durability may be combined with neatness and symmetry of form. It does not always occur that these are brought into one harmonious relationship. Between pleasing the eye merely, and doing good work, the latter is, of course, to be preferred.

Boilers.—By far the greater number of portable engines are supplied with horizontal fire-box boilers. This style of boiler is quite a favorite one with most manufacturers because it offers at once a convenient support for the engine, a good distribution of weight on the wheels, large fire-box capacity, good circulation, ample steam room, and has good steaming capacity with ordinary fuels.

The Materials of which the boiler is made may be either iron

or steel. In case steel should be used it should be no thinner than if the boiler were made of wrought iron; one-quarter inch plates are commonly used for this purpose. The tensile strength of the plates when made of iron should not be less than 45,000 pounds per square inch of section. The flange sheets will perhaps average not less than 60,000 pounds tensile strength.

Riveting.—It is not customary to double rivet the seams in 8, 10, or 12 H. P. portable boilers. The pressures at which they are used are so low in proportion to the strength of the structure that it is generally considered amply strong with the single row, no objection exists, however, to the double riveting, in fact it is always to be preferred, because the strength of the joint is increased twenty per cent. thereby.

The Fire-Box should be made of the best quality of charcoal hammered iron, or steel. The plate should be long enough to avoid a row of rivets above the grate bars if the construction is such as to permit it. In case steel should be used, its tensile strength should not exceed 65,000 pounds per square inch, and if a good ductile steel of 60,000 can be had, it is to be preferred. The fire-box should be large and roomy; it offers the very best kind of heating surface, and for this reason a long fire-box with short tubes is to be recommended rather than long tubes and a short fire-box.

The Crown Sheet should be arched and secured by stay-bolts running through to the outer shell.

This method of staying has many advantages over a flat crown sheet with its usual cumbrous crown bars and bolts. A very great objection to a crown sheet stayed by the latter method is in its impairing the circulation of the water at just the place above all others that the circulation should be free and uninterrupted; another objection exists in the fact that if the water used in the boiler contains salts of lime a hard scale will form underneath the crown bars and over the crown sheet, which not only prevents a complete transfer of heat, but will in a short time thereafter ruin the crown sheet by overheating.

The Stays around the fire-box should be ample to resist the highest pressure allowable on the boiler without permitting a bulging of the plate between them. The diameter of the stay-bolts will be fixed by the thickness of the plate, and their distance from center to center by the pressure to be carried. For one-quarter inch plates a three-quarter inch stay-bolt is as large as should be used, it should accurately fit into both sheets and and after screwing into place should then be carefully riveted over at both ends. For 80 pounds pressure the distance from center to center on the flat portions of the fire-box should measure 4⅝ inches; for 100 pounds 4¼ inches, or for 70 pounds, 5 inches will suffice.

In case a stay-bolt should break, the repairs should be made immediately, meanwhile, if it is necessary to use the boiler, it should be at a reduced pressure, or disastrous consequences are likely to follow.

Tubes should be of the best quality, expanded into carefully fitted holes, and may be from two to three inches in diameter; if less than the former diameter the draft is likely to be sluggish and they will be more apt to fill up with soot and ashes; if larger than the latter, too much heat is likely to be lost by passing off into the chimney.

Most manufacturers have adopted 2½ inch tubes as a standard for portables and from which excellent practical results have been obtained. Tubes should be kept clean by using a good wire flue brush or scraper, and as it requires but a few minutes to clean the tubes it should be done every day. In case tubes get to leaking, they should be re-expanded and caulked tight. A small leak around the end of a tube will soon cut a groove in the tube plate and furrow the tube so as to make it a very difficult thing to repair.

Ferrules are often used at the ends to insure tightness after the tubes are somewhat worn; these are simply iron rings having a tapering diameter on the outside and tightly driven into the leaky tube. This is only a temporary makeshift and is not to be regarded as restoring the tube. When the ends of the tubes are

very much worn they should either be repaired by cutting off the ends and welding on a new piece, or new tubes inserted instead.

Copper Thimbles are sometimes used in connection with the tubes to make a better joint. When used, the tube sheet is bored out enough larger than the tube to allow a copper ring to slip over the end of the tube and also tightly fit the hole. In expanding into place the copper makes a tight joint with the tube plate, and at the same time increases at least twice the ordinary length of the joint.

This is not a common practice in the construction of portable boilers but it is a good one.

Tube Sheets should be made of the best flange iron or steel. The flanging should be carefully done, and when completed must be free from flaws of whatever kind.

Cast-Iron Fronts to fire boxes are often used, and should be examined frequently to see that the lining is in good condition. When repairs are needed they should be promptly made, the best fire brick and fire clay should be used. A neglect to make the repairs when needed, will warp, crack or entirely destroy the front in a short time.

A Water Front forming a part of the boiler is to be recommended rather than a cast-iron front. The heating surface and water room of the boiler are both increased by its use.

The Fire-Door Ring should be made of wrought-iron rather than cast. The outer and inner plates of the fire box should be carefully chipped and calked against the ring. The fire door may be of cast-iron; it should have a butterfly register or other openings through it, and fitted with a perforated plate an inch or two back of the door proper, this will prevent loss of heat by radiation and destruction of the outer plate by warping.

Water-Bottoms are often attached to portable boilers, especially those intended for the Southern market. The talking point about it is that of affording the greatest security against fire occasioned by

dropping of live coals; it also affords, when ample space is allowed between the two lower sheets, a better facility for cleaning than that offered by the open bottom; there being a less violent movement of water in this than other portion of the boiler the sediment and impurities are likely to collect here and may easily be blown out out or removed through the hand holes. The water bottom does not add to the heating surface of the boiler.

Open-Bottom Fire Boxes are in more general use than those just referred to in the above paragraph. The ring at the bottom of the fire box should always be of wrought-iron. This form of fire box gives excellent satisfaction and is much less liable to corrosion than when fitted with a water-bottom. A strong wrought-iron ash pan should be attached underneath with suitable hooks.

Hand Holes should be placed so as to admit of thorough cleaning and examination of all parts of the boiler. There should be one over the crown sheet, one under the tubes in the smoke box, and one at each corner of the fire box when fitted with an open bottom, and one at each end when fitted with a water bottom. These openings should be as large as practicable and convenient.

A Fusible Plug should be inserted in the crown sheet at its highest point; it consists usually of a brass shell filled with an alloy consisting of tin, lead and bismuth, which will remain solid so long as there is water over it, but which will melt if the water falls below its upper surface, and thus permit a flow of steam into the fire box and put the fire out before any damage occurs; the proportions of the alloy being such that the melting occurs before the iron reaches a red heat. The object of its insertion in the boiler is to prevent a collapse of the crown sheet from overheating through a shortness of water.

Too much dependence must not be placed on the certain working of the fusible plug, as experience has shown that its efficiency has been greatly overrated, not that the metal failed to melt at the right temperature, but because an accumulation of scale had been allowed to form over its upper surface and of sufficient *strength* to withstand the boiler pressure without breaking.

Whenever the hand-hole plate over the crown sheet is removed the plug should be examined to see that no scale is forming over the top of it. Should there be it may easily be removed and cleaned with an ordinary knife blade.

Gauge Cocks.—Three gauge cocks are generally furnished with each boiler, the bottom one should be placed about an inch above the crown sheet, and each of the others on one inch centers above this. The water should be carried up to the center gauge cock which would then give two inches of water over the crown sheet. This is ample for good steaming and should not be exceeded. Compression gauge cocks, or plug cocks are to be preferred to the Mississippi gauge cock.

In case of leakage they may easily be ground to a fit by using very fine emery and oil.

Glass Water Gauges should be attached to some convenient part of the boiler where there will be little danger of the glass tube being broken by the handling of coal, ashes, etc.

It is preferable, as a general thing, to place it on the side rather than the end of the fire-box portion of the boiler. To support the gauge fittings and thus keep them in line, it is a common practice to attach the top and bottom fittings to an iron barrel which shall have a pipe leading from the ends into the water and steam spaces in the boiler. These connections should be tapped out for not less than a half-inch pipe, and if for three-quarter inch it is better still. Too much dependence must not be placed on the glass gauge as it is liable to become clogged and thus give false indications as to the water level. It should be used only in connection with the gauge cocks.

A Surface Blow is sometimes attached to portable boilers and serves a very useful purpose in skimming from the surface of the water any impurities which collect there and lower the steaming capacity of the boiler. A perforated pipe extending under the water line is frequently used, so also is a flat funnel-shaped opening, sometimes a collecting pan or basin, is used, all with more or less satisfactory results.

Unless the water to be used is likely to form a floating scum, the surface blow may be omitted without impairing the efficiency of the boiler.

A bottom blow should be placed somewhere in the lowest water space in the boiler. As a general thing it is located in the throat sheet, underneath the cylindric shell of the boiler. As there is more or less dirt, grit, and particles of scale which are likely to lodge there, a cock is to be preferred to a valve.

The Pump should receive special attention at the time of selection, and carefully watched afterwards when in use. The pump valves should be large, strong, of good hard gun-metal working in gun-metal cages or other suitable guides, they should be easily accessible, and of the simplest construction.

The pump plunger is usually driven directly from the cross-head, sometimes by means of a separate eccentric, and in rare instances an independent steam pump is attached to the boiler.

A supply or feed cock should be attached at any convenient place below the lower pump valve; this should be adjusted so that a continuous flow of water will be passing into the boiler which shall exactly equal the quantity of water converted into steam. The practice of opening the feed to its full extent and filling up the boiler to nearly the upper gauge cock and then shutting it off altogether for a time, is all wrong, and no man who understands the management of a portable, or any other kind of an engine will do it.

To determine whether the pump is working or not, a pet cock is introduced above the delivery valve of the pump by which it may be tested. As the pumps are usually single acting, the flow of water from the pet cock will be when the plunger is approaching the valves, and ceases when the return stroke is begun. Sometimes the pet cock is placed in the feed pipe. Another pet cock is attached to the middle chamber of the pump or that into which the plunger works, it is useful when starting the pump to rid this chamber of air which may have collected there.

The Supply Pipe to the pump is commonly a piece of heavy rubber hose three-quarters or one inch in diameter; this hose need not be more than five or six feet long, or long enough to reach from the pump into a barrel containing the feed water for the boiler.

A Strainer and Foot Valve are easily combined and should be attached to the end of the hose referred to in the preceding paragraph. This, if properly made and kept in order, will prevent chips, straw, leaves, etc., from working into the pump. The foot valve will hold the water up to the pump, and thus allow it to begin work as soon as the supply cock is opened.

A Check Valve should be large and strong and so designed that it may easily be taken apart for cleaning or repairs. Most of the small check valves made for the trade are too light and too delicately proportioned to stand the wear and tear to which they are subjected in portable engines. In the attaching of a check valve to a boiler a stop cock should be placed between the two, so that in the event of the check not working, it may be examined without having to blow off the boiler. As soon as the examination of the valve is completed, and the parts restored, this cock should be opened; and under no circumstances should the pump be set working until it is known that this cock is open, as a neglect to do so will result in breaking something about the feed apparatus.

A Relief and Safety Stop Valve similar to that by Mr. C. P. Wiggins, St. Louis, Mo., will be found a convenient and desirable attachment to a portable engine, by its use it would be impossible to break down the pump or burst the connections leading to the boiler in case the cock between the check valve and boiler should happen to be shut.

This valve is so constructed that there are three openings leading into the valve chamber of which only one can be closed. The valve itself is double-seated having a face above and below, so that on starting the pump the water will either be forced into the boiler or escape into the open air, depending on the position of the valve, in either case there would be no harm done the pump or

connections; the flow into the boiler may thus be recognized at sight.

Injectors and Inspirators are rarely applied to portable engines. The reason for their non-adoption no doubt lies in the difficulty heretofore experienced in operating them in connection with hard water, owing to the formation of scale in the interior passages or nozzles.

If, however, the water to be used in the boiler is clean, pure and soft, then there is no other device now in the market which surpasses them in compactness, reliability, simplicity, and ease of management.

The fact that they may be operated at any time when the steam is on, places them at a very great advantage over a pump driven from the cross-head of the engine, as the latter can be used only while the engine is in motion, the former may be used at all times whether the engine is in motion or not.

A Heater consists merely of a large pipe or a suitably cored chamber in the engine bed plate, into which the steam from the cylinder is exhausted at each stroke; this pipe or chamber contains two or more lengths of, usually three-quarter-inch wrought iron iron pipe, through which the feed water passes on its way from the pump to the boiler. The exhaust steam surrounding these pipes gives up much of its heat and by raising the temperature of the feed water a gain in fuel is had, as well as, reducing the wear and tear of the boiler resulting from the use of cold feed water. To get the greatest economy, the flow of water through the pipes should be continuous and not at long intervals.

The Safety Valve should be, both valve and seat, of some non-corrosive material, such as gun-metal, or bronze.

There are several very good safety valves now in the market and in the selection of one for a portable engine preference should be given to a self-contained spring valve rather than one combining a lever with the spring balance, or one fitted with a weight and lever. The latter kind is seldom met with on portable engines of recent construction.

The valve should be set to blow off at a certain fixed pressure and then fastened by some device which will prevent any change in the tension of the spring by the loosening or slacking of the adjusting screw. As a general thing, portable engine valves are set to blow off at 80 pounds per square inch for new boilers.

Every safety valve should be made so that it can be raised from the seat at any time, and thus insure its being in good working order. As the safety of the boiler often depends wholly upon the efficiency of this valve, too much care cannot be bestowed upon it, especially when in use.

The Steam Gauge should be of the very best construction and conveniently located on the boiler so that the pressure may be noted at short intervals. The two leading types of gauges are: the "Bourdon" or some modification of it, and the diaphragm gauge. There are many things which may be said in favor of both kinds of gauges, it matters little which kind may be selected provided the gauge is a good one and is reliable in its readings under a long continued pressure. A syphon should be attached to the gauge which will collect the water of condensation and thus prevent the direct contact of the steam with the spring of the gauge.

A Steam Blower will be found very useful in quickening a sluggish fire before starting the engine. It consists merely of an ordinary globe or angle valve by which the flow of steam from the boiler into the smoke-stack is regulated. The fittings are usually of a size corresponding to that of a half-inch wrought iron pipe. The end of the pipe entering the smoke-stack should be reduced to not more than one-quarter inch in diameter. When the engine is started the blower should be shut off, as the exhaust steam will cause all the artificial draft needed.

The Whistle should be of small size and fitted with an automatic valve, and lever. The connection from the whistle to the boiler should be straight as possible, the bends, if any are required, must be such that the water of condensation will drain back into the boiler. Severe cases of scalding are likely to follow neglect in drainage.

The Smoke-Box is usually a continuation of the shell of the boiler to a distance of about ten inches, and fitted with a cast iron plate having a door or other suitable opening for getting at the tubes. The smoke-box should be cleaned out frequently and especial care should be taken that no soot and cinders accumulate around the lower flange of the head, as it is likely to produce a leak after a time, by the corrosion of the plates with which it comes in contact.

The Smoke-Stack should have a strong cast iron base firmly attached to the smoke-box. The stack should be arranged with a device for lowering it when the engine is to be hauled from place to place. A strong cast iron ring riveted to the stack and hinged to the lower half, or that part riveted to the smoke-box, is perhaps the best arrangement now in use.

There have been many devices invented and attached to smoke stacks for arresting sparks, but a good and efficient spark arrester is yet a thing of the future. For arresting the heavier particles, such as cinders, etc., the stacks which have given the best satisfaction are those in which the current of escaping gases is abruptly changed, or reversed for a short distance, this has the effect to project the heavier particles downward into the smoke-box, from which they may be removed at any time.

A very common method of making a stack is to have a wire cloth screen across the top. This should not be too fine or the meshes will fill up, nor too coarse for it will then allow the escape of too large pieces of live cinders. This netting should be made of steel in preference to iron wire; and should be made ten meshes to the inch, No. 19 wire. This netting should be attached either to a hinged cap or fastened to a hinged or swinging frame at the top of the stack, the object being to add to the convenience in cleaning it and also to afford a better draft on a rainy day, by allowing the whole screen to be raised and thus permit the escaping gases to pass out underneath it.

Boiler Covering.—The close competition and consequent low price at which portable engines are placed in the market is the *common* excuse manufacturers give for not covering the boiler

with a non-absorbing substance, and thus prevent the great loss of heat by radiation. It is the common practice in locomotive works to cover the boiler with narrow strips of wood and then cover the whole with sheet iron. This forms a most excellent covering, and is of extremely light weight, besides being very durable. If all portable boilers were similarly covered it would add greatly to their economy.

Vertical Boilers are sometimes supplied portable engines but their use is not very common, being confined to certain localities rather than a general admixture throughout the whole trade. The chief merit of a vertical boiler is that it contains the greatest amount of heating surface with the smallest weight of shell, and the least quantity of water. To offset this, vertical tubular boilers are more apt to prime than the ordinary portable boiler on account of the deficient circulation between the tubes over the crown sheet.

It has long been, and still is, the practice of boiler makers to put in too many tubes in vertical boilers; this is done for the purpose of making the heating surface appear large and thus give the boilers a higher rating than that to which they are justly entitled. By reducing the number of tubes so that their combined area of cross section is merely sufficient to carry off the products of combustion, will make a boiler in every way superior to that usually built in which no regard is paid to circulation.

If this detail of construction be properly attended to there is then, other things being equal, no particular objection to a vertical boiler for portable engines; in fact a great deal might be said in its favor.

The Engine should be strong, simple, and durable; this requires that it be of good design, materials and workmanship. Whether the engine shall be horizontal or vertical matters but little, as an engine properly designed for the work and adapted for either position, will do good work in either position. The arguments both for and against these two styles of engines nearly balance each other. As a general rule horizontal boilers are supplied with horizontal engines, and vertical boilers with vertical engines,

but occasionally portables are seen in which the order of things are reversed.

There is a difference of opinion as to whether an engine intended for a horizontal boiler shall be fastened to the side of the boiler or on the top of it. Most builders place the engine on the side and either carry the shaft across the end of the boiler or locate the engine high enough to permit the shaft to pass over the top of it; others prefer to make the engine self-contained and place it on the top of the boiler.

The Cylinder should be made of hard iron and accurately fitted. It should be well fastened to the bed and so designed that it may be removed without taking out the tap bolts which secure the bed to the boiler. In rare instances an engine is seen in which the cylinder and bed are cast in one piece. In such construction the cylinder should have an extra thickness of metal to allow for repeated borings, or what is better still, the cylinder should have a lining in it, which may be easily removed and a new one substituted when repairs become necessary. Whenever possible the steam chest should be included in the same casting with the cylinder. So also, the exhaust passage should be continued around the cylinder to any convenient point where a proper connection can be made with the heater; one which shall permit the disconnecting of the exhaust without interferring with the bolts which secure the cylinder to the bed. In some engines the heater is placed directly underneath and the exhaust passage is continued around so much of the cylinder as may be necessary to join the two flanges by a single joint; this greatly simplifies the construction and is a good practice if either or both ends of the heater are left free of any obstruction.

Steam Jackets are seldom applied to portable engine cylinders and it is doubtful whether the trade would pay for the increased cost of construction. The outside cylinder casting and the inner lining in which the piston works should be two separate pieces with a steam space between them which shall completely encircle the inner cylinder from end to end.

This jacket should have direct communication with the steam

room of the boiler, so that it may be filled with live steam at full boiler pressure at all times, and the jacket should, from its lowest point, drain back into the boiler any water of condensation which may accumulate there. This connection should be entirely independent of the steam supply by which the piston is driven, because, if the supply is made to pass around the cylinder in order to reach the steam chest, some of the steam will be condensed and the water of condensation will be carried over into the cylinder, and thus any gain which might be secured by an efficient jacket will have been lost.

Lagging a cylinder saves heat by preventing radiation. It has long been a practice, and an excellent one, to lag the cylinder with narrow wood staves and covering the outside with sheet metal, or perhaps reeding the staves and finishing the ends with a narrow strip of sheet brass. Sometimes a sheet metal cover is attached to the flanges and the space between filled with plaster of paris or some other non-conductor.

A metal lagging attached to the flanges with an air space between the cylinder and the lagging will also prevent a great deal of loss by radiation if the air space has no circulation or currents in it connecting with the atmosphere.

The Main Valve or the one which regulates the admission of steam into the cylinder may be any one of several well-known designs, usually, however, it is either the common flat-faced D slide valve, or a rotary valve, or a piston valve. The first of the three named is in more general use than any other valve ever introduced. The rotary valve is not correctly named, as the rotation is only partial, the valve and seat instead of being flat are made circular, in other respects it does not differ in its action from the plane slide valve, except, of course, by the manner in which it is operated. The piston valve is oftener met with in small stationary engines than in portables, and it is in all respects a good valve when properly made and applied.

The only attention the valve requires is that it shall be kept well oiled, not excessively, but sufficient to keep it in good wearing condition. For this purpose a valve lubricator is attached

to the steam chest. These are rarely automatic in their action and will require more or less attention on the part of the attendant.

The valve should always be properly set when the engine leaves the shop, and should never be disturbed except for repairs or other good reason.

The Steam Chest Joint should be properly made after taking off the cover to examine the valve. There is perhaps no better joint for this purpose than that made with a layer of vulcanized rubber packing; this need not be very thick if the joints are in good condition, say one-thirty-second inch or perhaps a trifle heavier. A spare gasket should be kept on hand at all times, as it often happens that the one in use is torn in the removal of the steam chest cover.

The Piston will need but little attention except to keep it well lubricated. The rings seldom need adjusting, and when they do, it should be only sufficient to prevent the steam from flowing past the piston from one end to the other of the cylinder. Young and inexperienced engineers make a great mistake in tightening the piston rings at every opportunity. The only effect is to produce more friction and thus wear out the cylinder in a shorter time. Some manufacturers pay a considerable royalty for a self-adjusting piston packing in order to relieve themselves from the annoyance caused by this habit of setting out the packing rings when it is wholly unnecessary.

The Piston Rod should be made of steel and must be kept entirely free from rust. The stuffing box should be large and kept well filled with a good packing of which there are several varieties now in the market, and may be purchased at any machinery depot or large hardware store. If this cannot be had, a plaited gasket made of jute or hemp may be used, which after being laid up in three or more strands should be soaked in melted tallow and then driven into place with a wooden packing stick. Never use a metal packing stick as it will mark the rod and *cut out the packing* in a short time after starting the engine. Do not

screw the packing too tight, all that is needed is that it shall prevent leakage of steam. Be careful that the gland is screwed up evenly, and that it does not bind the piston rod. Keep the piston rod well oiled and see that it is always bright and clean.

The Valve Rod and stuffing box are to be cared for in a similar manner to the above.

The Cross-Head must be kept clean and well oiled. After every run it should be thoroughly wiped to remove any cinders and dust which may have collected on or about it. Ir needs no special care except to see that it is working free, and is well cared for.

The Guides need no other attention than to be kept clean and well oiled.

The Connecting Rod will require constant care and watching, the crank-pin end more so than the other. It is absolutely essential that the flow of oil be constant and regular in order to get the best results. For this purpose an oil cup should be provided which shall deliver to the crank-pin a certain amount of oil at each stroke of the piston.

When the brasses are somewhat worn they should be adjusted by keying the strap a little tighter, or otherwise adjusting the boxes if the connecting rod is not fitted with strap joints.

This should be proceeded with very cautiously, for if too tight the brasses are sure to heat, and cutting of the pin will inevitably follow. It is on the whole better that the boxes are made to fit brass to brass and keyed up solid, then, if further adjustment is needed, file off slightly from the edges of the boxes and replace in the strap, keying up as before.

After the engine has been in use a few months and several adjustments of the connecting rod have been made, the rear cylinder head should be removed and the clearance measured between the piston at the end of the stroke and the cylinder head when in place. If this distance is less than one-sixteenth inch it becomes dangerously close, and liners should be placed back of the connecting rod brasses to carry the piston forward to the original

position which it occupied when it came from the shop. It may perhaps be better to put in a new set of brasses in the connecting rod.

The Crank-Pin should be made of steel and must be carefully watched that it does not heat. When once a crank pin has been overheated, and especially if it has ever cut itself into ridges or grooves, it is very difficult to get it to run smooth and cool thereafter.

The Main Bearing will require to be carefully looked after, first to keep it from heating, and second to keep it in line; that is, see that the side boxes are so adjusted as to keep the main shaft in line. Other than this it requires no special attention.

The Rear Bearing must be so adjusted as to work in line with the main bearing. The fly-wheel or pulley is usually located near the rear bearing and as it has to take all the strain of the belt it should receive careful attention.

A Cranked Shaft is generally used on engines which are located on the top of the boiler, these have a bearing on each side of the crank. Engines of this design are usually supplied with two pulleys, a large one on the one side, and a smaller one on the other. Such shafts are usually large for the work required of them, and will need little else than to see that the bearings are properly oiled.

The Fly-Wheel for portable engines is generally made with a wide heavy rim suitable for driving directly from it. Sometimes these wheels are so out of balance as to seriously interfere with the otherwise smooth working of the engine; particular attention should be given to this matter in the shop and no fly-wheel or other pulley intended for a portable engine should be placed in position until it is perfectly balanced.

A smaller pulley is often placed on the same shaft for driving machinery at lower speeds than the larger one will admit of, on account of its size.

To find the rate of revolution at which a pulley would be driven by the engine, is found in this way: Multiply the diameter of the pulley on the engine shaft, in inches, by the number of revolutions per minute, then divide this product by the diameter in inches of the pulley to be driven, the quotient will be the number of revolutions per minute.

Example: An engine fly wheel is 42 inches diameter and makes 180 turns per minute; how fast will it drive a pulley 7 inches in diameter?

42 multiplied by 180 equals 7560.

7560 divided by 7 equals 1080 revoltions per minute, the answer required.

The Eccentric, next after the crank-pin, requires more attention than any other part of the engine. The straps should be as loose as possible and not rattle; if too tight, they are likely to heat and cut fast. The best way to adjust them is to insert between the lugs where they are bolted together, tin or other thin washers, and then tighten the bolts so as to make, practically, a solid ring. After a time, when they will need readjusting, one or more pieces of tin may be taken out and the straps again bolted together.

The eccentric should be keyed to the shaft rather than fastened with set-screws. A very good way to secure an eccentric and one which is sometimes practiced by portable engine builders, is to fit the eccentric to the hub of the crank, and then hold it in place by means of a bolt passing through the crank and screwing into the eccentric. Such a thing as slipping by this arrangement is impossible.

By simply drilling and tapping two holes at the proper positions in the eccentric, the engine will be be enabled to run over or under as circumstances may require.

The Valve Connections should be simple and direct. If a knuckle-joint is used, or small strap joints, they should be well oiled, and if it is necessary at any time to adjust the connections, care should be taken that the pins in the joints be left exactly at right angles to the throw of the eccentric, otherwise an undue

strain will be brought to bear on the joint which will soon destroy its accuracy.

A Link Motion is not generally applied to portable engines except in such cases as need a prompt reversible motion, such for example, as in wharf work, pile driving, mining, etc.

A Governor for a portable engine should be quick and sensitive in its movements at any variation of speed. It is important that it be of the best materials and thoroughly well made. There is nothing about a portable engine likely to give more trouble than a poor governor. It ought, therefore, to have a certain adaptability for the place in which it is to be used; and the graduation of the governor valve should be such as to adjust the pressure in the steam chest to the load on the engine without wide and extreme variations, as this is likely to produce a great irregularity of motion in the engine, or racing, as it is generally called.

The governor belt should be of a width best suited to the governor. In general, a narrow leather belt well filled with some one of the various "belt stuffings," or with castor oil, will be found to be reliable under almost all conditions. A tightener should be attached to the engine whenever practicable, as it will allow slight variations of length to be taken up without having to stop the engine and shorten the belt, it will also prevent the belt slipping and so keep the governor running at its regular rate.

A safety attachment is applied to many governors now in the market, by which the engine is stopped at the same time the governor stops running. Such a device cannot be too heartily commended, provided the remainder of the governor mechanism and the governor valve are in all respects equal to the best governors which do not have this safety device. All things considered, it is better to have a good governor without the safety device, than a poor one with it.

The Steam Pipe should be as short and direct as possible; it should, at some convenient point between the boiler and the governor have a good strong globe, or other stop valve. This valve *is generally called* the throttle valve, but it ought not to be such

in reality. When the engine is once fairly started it ought then to be opened wide, and let the governor take care of the engine.

The Exhaust Pipe leading from the heater to the base of the chimney is generally large and roomy, but at the end of it there is either a contracted nozzle forming a part of the pipe, or it is fitted with a removable nozzle by which any desired concentration of the exhaust steam may be had for the purpose of forming at the base of the chimney a strong blast to assist the furnace draft.

The smaller the nozzle the more intense the blast, but at the same time there is an increase of back pressure on the piston, which takes off just so much from the power of the engine. The diameter of the nozzle should be no smaller than that necessary to keep up steam under a full load.

Drain Cocks should be provided at any point where the water is likely to collect, and in freezing burst a pipe or fitting. These should be opened at night so as to drain all the pipes perfectly dry.

The Wagon supplied portable engines is of the simplest description; about the only real difference among manufacturers is a wrought-iron axle passing under the boiler at the fire box, while others secure a short wrought-iron axle to a cast-iron bracket which is then bolted to the sides of the fire box. The forward axle is in all essentials the same for all engines.

There is a wide difference of opinion as to whether wood or iron wheels shall be used. Most portables are now fitted with wooden wheels, but the iron ones are steadily growing in favor. An iron wheel may have a cast-iron hub but the arms and tire should be of wrought-iron.

A Brake should be attached to all portable engines intended for use in a hilly country. The handle should be within easy reach of the driver, and the strains on the brake rods should always be those of extension rather than of compression, for if of the latter they are likely to be bent and thus rendered inoperative, perhaps at a time when most needed.

The Tools Required for a Portable Engine are not numerous, but include a shovel, scraper, slice or hooked bar, flue brush, screw wrench, packing hooks, hand hammer, and oil can.

Directions for Running a Portable Engine:—

1. Get the engine into position and see that it stands perfectly level, and that the belt is in line with the machinery to be driven.

2. See that the engine is perfectly clean in all the wearing parts, and that the hand-hole plates are all in position and the boiler ready to be filled with water.

3. Fill the boiler with water to about two inches above the crown sheet, or up to the second gauge cock.

4. Examine the pump and see that it is clean and in good working order. Examine the supply hose, strainer, and foot valve.

5. Procure a tight, clean barrel for the water supply and place it near the pump. This barrel should always be kept nearly full of water.

6. Examine the packing at the piston and valve rods. It is true economy to pack these often, and it should not be allowed to get hard and brittle, as it will not only be difficult to keep the steam from flowing through, but will scratch and groove the rods.

7. Start the fire, using plenty of good dry kindling, but do not force it; let the fire burn slowly at the start, as it will save many a leak and add months, if not years, to the life of the boiler. When the boiler begins to steam the blower valve may be opened slightly and thus increase the draft, shutting it off when the steam is up nearly to the running pressure.

8. Oil the engine, open the drain cocks to the cylinder, and to the heater.

9. See that the governor and belt are in good working order.

10. Turn the engine over by hand to see that everything is free, then open the throttle valve and allow the engine to run for a few minutes, quite slow. When the cylinder is warm and no water of condensation escapes from the cylinder cocks, they can be closed and the throttle opened wide.

11. See that the valve or cock between the check valve and the boiler is open; then place the supply hose with the foot valve

and strainer in the barrel of water, then partially open the supply cock under the pump, open the pet cock in the pump barrel to expel the air, put your finger over the opening in the pet cock to prevent the flow of air into the pump when the plunger is withdrawn, and as soon as the pump plunger forces out water instead of air close this pet cock, and then examine the check to see if it is working.

12. Keep your eye on the glass water gauge and be sure that it is indicating the true water level, as shown by the gauge cocks.

13. Try the safety valve several times during the day and see that it is in good working order. At the same time see how nearly it and the steam gauge agree.

14. Fire regularly, and not at all sorts of irregular intervals. Keep the grates well covered and do not allow air holes to form in the fire. The fire should be kept clean, but do not rake the fire as long as the ash pit remains bright. Do not let the ashes accumulate under the grates, but keep the ash pit clean.

15. Adjust the water supply by means of the cock below the pump so that a continuous feed is had which shall just equal the evaporation. Keep the water-level in the boiler at the second or middle gauge cock.

16. Never shut the cock between the boiler and check valve except when it is necessary to examine the latter. If it is necessary to close it while the engine is running be sure that the supply to the pump is first shut off, or an accident of some kind is sure to occur.

17. Blow out the boiler as often as once a week, when used steadily. If the boiler is accumulating scale a pint or so of crude petroleum might be put in the boiler the day before blowing out. Do not put coal oil in the boiler. If you cannot get crude petroleum put in two or three quarts of common molasses. The object of introducing these substances in the boiler is to loosen the scale if any has formed. After blowing out, the boiler should be carefully cleaned and thoroughly washed to be sure that the scale is all removed; after which a pound of sal-soda or better still crude tannate of soda may be put into the boiler and then filled with water.

It is highly important that the boiler be kept perfectly clean and free from scale.

18. In case of priming or foaming, slow the engine down a little by closing the throttle, open the fire door to check the fire, open the cylinder cocks, and increase the feed slightly.

As soon as the priming stops, turn the feed cock back to its regular place, shut the fire door, and if no water is blown out of the cylinder cocks close them, then open the throttle gradually until the engine works up to its regular speed.

19. Low water is always dangerous; if the water supply is ample and the pump in good working order there is no excuse for its occurrence, but when it does happen and the water disappears from the lower gauge cock, cover the fire with fresh coal, leave the fire door open, close the ash pit door or damper, but do not disturb the engine; let it use all the steam the boiler makes and allow it to run until it stops of itself. When there is no longer any steam in the boiler take out the hand hole plate above the crown sheet and see if it is bare, if not, or not overheated, then fill up the boiler to the second gauge cock, replace the hand-hole plate, open the ash pit door, close the fire door and raise the steam again as usual.

Finally, as it is not possible to enumerate all the things to which attention must be given in the management of a portable engine, it is expected that the person in charge will give it his whole time and attention, and that above all things the height of water, steam pressure, firing, lubricating, and cleaning, will be faithfully attended to.

When the season's work is over and the engine is to be laid up for the winter, the boiler should be perfectly cleaned inside and out, all the pipes, the pumps, the siphon, and everything else containing or likely to contain water, should be carefully drained. The fire box, tubes, ash pan, grate bars, smoke box, and chimney, should be perfectly cleaned. Take out all the packing from the piston, valve rod, governor and throttle valve stuffing boxes. Thoroughly clean all the bright work and cover with a mixture of *about* equal weights of white lead and tallow melted together and

put on with a brush or rag. Give the outside of the boiler, the fire box, ash pan, chimney and smoke box a coat of asphaltum varnish. Then run the engine under cover until next season.

When next season arrives don't put off until the last minute getting the engine ready for service. Take advantage of rainy days before harvest and have it ready for use at any time that it may be needed.

In case the engine should need repairs, have them made as early in the season as possible; it is as a general thing better on the score of economy to order new parts from the manufacturer than attempt to have them made in a country shop when such parts require special patterns and special tools to make them.

Traction Engines ante-date by many years the modern portable engine. As early as 1680 Newton proposed a steam carriage and furnished a sketch illustrating the principle on which it was to be constructed; but it is doubtful whether any steam carriage was actually experimented with until 1769 when one was constructed by an officer of the French army named Cugnot. From that time down to the present there has been no lack of devices for propelling the engine not only, but for hauling wagon trains as well.

Traction engines were originally devised to supersede horse-power on common roads, previously to the general adoption of railways. The demand for traction engines at this time is altogether from a different standpoint. They are not required for hauling trains so much as it is desired that a portable engine shall be capable of self-propulsion. This has stimulated manufacturers to the perfecting of an engine which may be used in all respects as an ordinary portable engine is used, and when necessary will transport itself to a new position, or to a neighboring farm. This is about all that can reasonably be expected of a portable engine at present.

Traction engines have been in very common use in England for several years, and with greater or less success. This by no means proves that such engines will be equally serviceable in this country. The conditions of the roads in the two countries are different. If we had a system of well-kept gravel roads, or turn-

pikes in the farming districts, then a traction engine might be very serviceable in drawing heavy loads in wagons.

Most manufacturers in this country construct their portable engines with single cylinders. The regular design of engine intended for the ordinary trade is used, the traction portion consisting simply in the addition of a few parts over those regularly furnished. By this means the manufacturer is enabled to supply customers with either kind of engine without having to use two sets of patterns from the outset.

The parts required over the regular portable engine are geared driving wheels, with suitable pinion and shaft. This shaft sometimes contains a special train or assemblage of gears known as differential gears, or more commonly "a jack in the box." This consists essentially of two large bevel wheels, and bevel pinions working into both of these wheels. These pinions are secured and revolve freely in a circular frame which is also free to revolve around the shaft; it is through this circular frame that the power is applied, which may be either by means of a gear wheel or a chain. One of the large bevel wheels is keyed to the shaft and which also has secured to it a pinion gearing into one of the main driving wheels; the other bevel wheel slips loosely over the shaft and is usually fitted to a sleeve or pipe, and which is also fitted at its further extremity with a pinion which gears into the other driving wheel.

The power is applied through the revolving frame carrying the pinions, and so long as there are no obstructions the driving wheels both move together, but if it is desired to make a turn in the road it is obvious that the outer driving wheel will have a greater distance to travel than the inner one, in which case the inner wheel will make fewer revolutions, or may perhaps, for a moment at a time, be standing still while the other wheel will be in motion. This very necessary movement of the wheels may be accomplished by means of this combination of bevel wheels and sleeve already described.

Another method of arriving at the same end is to secure pinions at both ends of the shaft gearing into the driving wheels, and then *making* the hubs of the wheels in such a manner that a ratchet or

other device shall allow one wheel to advance in revolution over the other when meeting obstructions or turning a corner.

Traction engines should be made reversible, and there is perhaps no better device for the purpose than the ordinary link motion.

A good sized platform should be attached to the fire box on which the engineman shall be able to stand when the engine is in motion. This platform should contain a water-tank and a box for a reasonable supply of coal.

In ordering a portable engine with a traction attachment the steering gear should also be ordered at the same time. This will enable the engineman to have complete control of the engine on the road and will in no respect be dependent on the driver, and will also lessen the liability to accident.

CHAP. X.

CARE AND MANAGEMENT OF A LOCOMOTIVE.

The locomotive engineer or engineman, has, as a general thing, little or nothing to do with the design or selection of a locomotive engine. These are included in the general equipment, and the particular type and size of engines to be used are determined by the directors or some official delegated by them to make a suitable selection of rolling stock for the road.

The Engineman is placed in charge of the engine assigned to him, and is given an assistant who acts as fireman. The engineman exercises a general supervision of the engine while on the road, and directs, when necessary, the operations of the fireman. He should give his attention to the manner of firing, the performance of the boiler, the supply of feed water, the pressure of steam, and should be so conversant with the features of the road that the firing and production of steam shall be such as not only make schedule time in running, but do so with the greatest economy of fuel and the least wear and tear of the engine.

The duties of an Engineman are so varied that it requires a man of peculiar make up to be a success on the road. The time was when they were recruited from the ranks in the machine shop, and it was seldom that a man could get an engine to run unless he was also a good machinist. This practice was not found to be so necessary as it was at first supposed.

Now they are not required to be machinists, but serve for a time as a fireman, and are successively promoted from the charge of switch engines, local freight, through freight, local passenger, to the charge of locomotives attached to through express trains.

In getting an Engine ready to go out on the road, and before starting the fire, there should be at least one gauge of water in the boiler. The grates should be perfectly clean and free from cinders or clinkers, and should also be examined to determine whether they are securely fastened. See that the throttle valve is closed, and the link in mid-position.

Use dry wood in starting the fire and do not urge it, but let the the fire kindle slowly. Never try the experiment to see how quickly you can raise steam from cold water; there is nothing which will so quickly and effectually ruin a boiler as rapid and intense firing before the plates in the shell of the boiler are heated to the temperature corresponding to the pressure of steam nearly up to that at which it is to be used on the road.

When the fire is kindled, the fire-box is heated and expands, while the outside of the boiler is scarcely warmer than at first. The immediate effect is to expand the whole internal portion and so bring an undue strain upon the outer and inner portions of the boiler. This expansion is very complex because of the construction of the boiler and its system of bracing. The fire-box will expand in all directions, because it is heated on all sides; the bottom being rigidly secured by a ring to the outer shell of the boiler is prevented thereby from expanding downward, so that in addition to this cubical expansion there is also a movement of the whole fire-box upward; this has a tendency to loosen every stay-bolt in the sides of the fire-box, and the nearer the top of the fire-box the greater the expansion and the greater the strain brought upon the stays. The effect of the heat on the tubes is to lengthen them; as the outer shell of the boiler is cold, the action of the tubes is that of pushing through the tube sheets. Tubes are secured to the tube sheets by expanding and caulking only, and will soon, through improper management of fires in raising steam, become loose and leaky.

There is little doubt that much of the trouble with steel fire-boxes has had its origin in improper starting of fires. Let the fire then burn slowly until steam is raised.

When Steam is on the Boiler, and near the time when the engine is to be used, the cylinders should be warmed, the cylinder

—8

cocks opened, shifting the link occasionally that both ends of the cylinder may be warmed and all water of condensation allowed to escape.

The injector should be tried to see that it is in good working order. If it should be found to be out of order it should be taken apart immediately, cleaned and replaced; if it does not need cleaning the trial need not be of more than a few minutes duration, unless the boiler should be in need of water.

The engine should be thoroughly oiled before taking it out of the engine-house, examine the tank to ascertain the quantity of water in it; if fuel and water are needed the necessary supply should be furnished before the delivery of the engine for service.

Before starting the engine the bell should be rung as a warning for those engaged near it, or on the tracks, to get out of the way. Ample time should be given for this purpose, and the man in charge should satisfy himself that the track is clear before starting. Under no circumstances should an engine be started without this signal.

When out of the engine house, and as soon thereafter as possible, try the pumps and be sure they are in good working order.

In taking charge of an engine for the first time the engineman should see that there are no leaks around the boiler, and that the safety valves blow off at the pressure at which they are set, he should also know whether the spring balances of his safety valves are correctly marked. The steam gauge should be known to be correct. He should also satisfy himself as to the exact position of the lower gauge cock above the crown sheet. The throttle valve should be tested for leaks, this can easily be done when the engine is standing, by simply opening the valve in the oil cups on the top of the steam chests, if there is a leak the steam will continue to issue through the oil cups into the atmosphere; and in general satisfy himself as to the condition of everything about the engine.

In making up, or connecting with a train, the engineman and fireman should both be on the engine. The fireman should not unnecessarily absent himself from the brake on the tender, until *everything* is in readiness for the road.

The steam should now be up to the full running pressure; if the fire is sluggish the steam blower may be opened to quicken it, but should be closed immediately on starting the engine.

When the train is ready to start the engineman is then under the direction of the conductor. Upon the signal to start, which should always be by sounding the signal bell and not by the waving of the hand or lamp; upon this signal, the engineman should, before opening the throttle, cause the whistle to be blown or the bell to be rung, the latter should be used in preference to the former at all times, reserving the whistle for signaling when the train is in motion. The cylinder cocks should be wide open, the link should be placed at nearly or entirely the full throw of the valve, the throttle opened gradually so as to prevent the jerking of cars. If the train is a very heavy one, the engine should first be reversed and thus take up the slack of the train; this should be done cautiously that the momentum of the forward cars do not give motion to the rear car, the link is then to be quickly thrown into forward gear and the train started one car at at a time until the whole train is in motion.

In starting a train during wet weather or at other times when the driving wheels slip, the valves at the sand box may be opened and the rail slightly sanded. This should not be resorted to unless absolutely necessary, and then it need not often be of more than momentary duration.

Immediately after starting, the engineman must satisfy himself that the train is all connected, and for the first few minutes thereafter that it remains so. Link couplings are often broken in two in starting, sometimes only one side breaks and the train is hauled some distance before it parts the other side, or slips past the pin. On passenger and some freight trains this would be immediately made known by the sounding of the signal bell.

The engineman's attention must be given in starting from a station, to the engine itself, the track before him, and the train behind him. He must see that the switches are properly set and that the signals indicate a clear track. He must have the engine under perfect control and see whether or not any signal has been

given at the station for the stopping of the train after the one for starting had been given. Now that trains are run under the orders of a general train dispatcher, this recall is not an infrequent occurrence.

After starting a train, and it is seen that no water is being blown from the cylinder cocks, they should be closed. The speed, if running through a town, should not exceed four miles per hour, the bell should be constantly rung until outside the corporation limits. The engineer and fireman should both be on the lookout for obstructions, switches, signals, and for pedestrians and vehicles at street crossings. When outside the corporate limits the speed may be increased and the regular running time entered upon.

The Pressure of Steam should be kept fully up to that at which it is intended by the superintendent of motive power, or the master mechanic. There is a great saving of fuel by using high pressure steam for a portion of the stroke and then expanding to a lower pressure. It is necessary in starting a train to use the steam to nearly the full stroke of the piston, but, as the engine gains in speed, the link may be raised by moving the reversing lever toward the center of the quadrant. The notches in this quadrant are measured and the degree of cut-off stamped thereon, so that the engineman may know what portion of the stroke the steam is following. The weight of the train and the features of the road will determine what is the best point of cutting off in order to maintain a certain speed. This must be left entirely to the judgment of the engineman.

The Greatest Economy will be secured if the engine be run with the throttle wide open and the travel of the valve adjusted to the load.

This is subject, however, to some modifying circumstances. If the train is a heavy one, and the engine working up to nearly its full capacity, the best and most economical results will be attained; if, however, the boiler is defective in design, or the fuel bad, or the boiler too small for the cylinders, there is a possibility that the steam may be cut off so early in the stroke that after expan-

sion there is not force enough in the exhaust steam to create the necessary draft for the fire, and it will be found difficult to keep up steam. In this case the pressure may be lowered, or the throttle may be closed somewhat, the lever moved a notch or two further forward until the exhaust has sufficient influence on the draft to keep a brisk fire and the boiler furnishes the proper quantity of steam. This is the reverse of true economy, but it sometimes happens that it is the only way out of a practical difficulty.

The engineman has, of course, to give his main attention to the track and be on the lookout for signals, etc. Still, he should at all times know the condition of the fire, the height of water, and pressure of steam.

The Firing should be regular and frequent, and the fire itself kept constantly in that condition by which it is found to generate sufficient steam for the work to be done. It should under no circumstances be allowed to get so low as to affect the pressure of steam in the boiler. When approaching stations at which there is to be a somewhat lengthy stop, the fire may be charged with fresh coal and run for a short distance with the fire door open to reduce the pressure. When approaching the terminal station, the fire should be allowed to burn so low that there shall be only steam enough to reach the engine-house.

The management of the fire depends entirely upon the steaming capacity of the boiler, the fuel used, and the service in which the engine is employed.

The Supply of Feed-Water to the boiler should be regular and constant. If an injector is used, it should be only of such size as will permit a constant flow of water into the boiler. If pumps are used, the supply cocks should be adjusted so as to accomplish the same thing; in general but one pump is needed to supply the boiler under all ordinary conditions. The water should be kept at a height which will show two gauges of water when running on a level. When running up or down an incline allowance must be made for the change in level of water, especially when going down grade, that the crown sheet be not exposed to the action of the fire by uncovering.

Grades.—It is important that the water-level be carefully attended to when running over steep grades. Before ascending such a grade an extra supply of water should be fed into the boiler; this extra supply forms a reserve of water already heated to the boiling point at the steam pressure then employed. If the pressure of steam can be carried somewhat higher without blowing off at the safety valve, it is a good plan to do so, and will make this reserve of hot water in the boiler all the more efficient when needed. The engineman must decide for himself the quantity of water it is safe to carry over that regularly employed. If too much water be fed into the boiler it is very apt to cause priming.

In running down a grade the water-level will require to be nearly as high as when going up a grade. The water should, on the steepest descent, cover the rear end of the crown sheet at least an inch.

Features of the Road.—One of the first duties of a person employed on a locomotive engine, apart from its care and management is to learn the features of the road. No parts of the road require greater vigilance and caution in running over them, than the up and down grades. It is quite a common occurrence that in addition to these grades there are sharp curves, tunnels, bridges, and trestle work.

It is obvious that mere training in mechanical skill, in technical knowledge of the locomotive, or even a thorough knowledge of the road bed from one end of the line to another, will not of themselves make a man a fit person to have charge of a locomotive. He must possess at least this much of knowledge and skill, but he must in addition, have a good clear brain, cool judgment, steady nerves, good eyesight and entirely free from color-blindness, he must be quick to discern and prompt to execute.

Priming may be caused by impurities in the feed water, but oftener perhaps by the insufficiency of the boiler for the duty required of it. The evaporative capacity of steam boilers is not as a general thing equal to the maximum capacity of the cylinders in rdinary passenger and freight engines. The practice is becoming ore general to furnish larger boilers for the same cylinders than

was customary a few years since. With these larger boilers there will also be less of priming.

Priming may easily be detected by the motion of the water in the glass water gauge, or by the "flutter" of the gauge cocks when opened. Priming may also be detected by the change in the sound and color of the exhaust; the sound being heavier, and the escaping steam whiter and has a misty appearance. As soon as priming is observed the cylinder cocks should be opened and kept open so long as the water is seen coming from them, the fire door should be opened, and if there is plenty of water in the boiler the feed may be shut off; the throttle valve should be partially closed which will allow a pressure of steam to accumulate and so determine at once the true water-level, if below that at which it should be carried, the fire door may be closed and the pump set to working, still keeping the throttle partially closed until the water begins to rise in the boiler, and the pressure of steam to accumulate, after which the throttle may be again opened gradually, until the regular speed is attained.

Oiling.—This duty usually belongs to the fireman. Good oil, and the best oil cups for the purpose, only should be used. When arriving at a station one of the first things to be done is to examine the several bearings to ascertain whether or not they have become hot, dry, or cutting. This can be done very readily by an experienced person by sense of touch. Mineral oil is commonly used for lubricating but a supply of good lard or sperm oil should be constantly at hand for use on hot bearings.

If the bearing is very hot it should be cooled with water before applying the oil.

The Supply of Water and Fuel in the tender should never be allowed to become fully exhausted. The location of these supply stations must be exactly known by the engineman and fireman and the supplies of both laid in at such stations as may be on the side of safety, if no regulation of the road require it to be done at particular points on the line.

Curves.—In approaching curves the speed of a train should be

less than on a straight track, the diminution in speed being in proportion to the radius of the curve; the sharper the curve the less should be the speed. The tendency of the train when entering upon a curve is to continue in a straight line, and, the greater the velocity the greater the danger of running off the track. Another reason for a slower speed in passing curves is the short distance at which the track can be seen in advance of the train. Should there be an obstruction on the track, or a danger signal, the train might not be stopped in time to prevent accident if running at a high speed.

Bridges.—When approaching a stream keep a sharp lookout for signals. The train should be slowed down to five miles an hour in crossing a bridge of any considerable length; if it is a wooden bridge the ash-pan damper must be closed until the opposite shore is reached. In the case of covered bridges, the engineman should be specially careful that no sparks or live coals and cinders be thrown from the chimney.

In case the bridge should contain a draw, the train must be brought to a full stop before crossing, and should not then attempt it until the signal be given that all is clear.

In Approaching a Station the speed should be reduced so that the train will not enter at an unsafe velocity. There are persons who will stand on the track about the stations, and are thus liable to be run over; there is always more or less of driving, loading or unloading of goods, etc., which sometimes temporarily encroaches upon the train limits. The steam should be shut off from the engine at a distance of half or perhaps a full mile before reaching a station, depending upon the grade and condition of the track.

It is safer to enter at too slow a speed than too fast, for it is an easy matter to give the cylinders more steam, if necessary, to bring the train to the proper position.

Continuous Brakes are now in such general use that no road is considered perfectly equipped which does not have them fitted to all the passenger cars on the line. By their application the train is placed under complete control of the engineman. The brakes

should, in all cases, be applied gradually and so prevent the disagreeable shocks and jerks to which the cars are subjected when applied suddenly.

The Duties of an Engineman are too various to be enumerated in a single chapter of a small hand-book like this; it is intended that only the more prominent duties required of him be given. A chapter on accidents might be added, but it would carry this subject beyond the narrow limits assigned it. In case of accident the judgment of the engineman and those employed on the train will decide what is best to be done. This mere outline of the duties of an engineman and fireman as here given will no doubt be of interest to those who wish to know something of what is expected of them, but who have no expectation of entering any railway service or of having to do the work themselves.

Color-Blindness is a defect of vision by which the person affected is unable, in a greater or less degree, to distinguish colors. This defect may either be congenital, *i. e.* color-blind from birth, or it may be acquired; it may also be complete or partial.

It would be entirely out of place to enter into the causes of color-blindness in this little hand-book. The only object in introducing the subject at all is to point out some of the possible dangers which might result in mistaking one signal for another.

Total color-blindness is quite rare and represents the entire inability of a person to distinguish between colors of any kind. To such a person there is simply a gradation of light and shade accordingly as the color may be of greater or less intensity. The visual effect upon a person who is color-blind in looking at an oil painting would be much the same as that upon another who could readily distinguish colors, were he to look at a similar drawing, executed in black crayon instead of colors. Such a person could not distinguish between a red, green or blue flag or lantern.

Partial color-blindness is by no means uncommon, and includes such defects of vision as arise from the inability of a person to distingnish one or more particular colors from others. Thus a person may not be able to distinguish a green from a red flag or lantern, yet may be able to distinguish a bright yellow, blue, and

some other colors. The three kinds of partial color-blindness most likely to occur are some of the following:—

1. Red-blindness.
2. Green-blindness.
3. Violet-blindness.

Although this classification is only partial, and somewhat unsatisfactory, it will nevertheless answer our present purpose, as the colors generally used in signals are white, green, and red; of which white indicates a clear track, green is a signal of caution, and red a signal indicating danger and which should cause the train to be brought to a full stop at once. The ordinary defect in reading signals by one who is partially color-blind is that of confounding red with green.

Any person who possesses this chromatic defect should not for a moment think of entering the service of any railway company, if he is to be employed on the trains in any capacity in which he shall ever be called upon to place or read signals. Especially should a person who is in training for a locomotive engineer be careful to satisfy himself in regard to this matter. Not the least of the requirements for an engineman or fireman should be the ability to read signals at night by momentary flashes, or the determining of colored lanterns at long distances.

Color-Blindness in Railway Employees.—The evidence furnished by recent examinations of railway men discloses the fact that color-blindness exists to an extent scarcely suspected a few years ago. In all cases where there is direct conflict of evidence as to the state of the signals, it would be at least advisable to have the witnesses tested for color-blindnesss.

"Dr. Keyser,* of the Wills Eye Hospital, Philadelphia, has recently examined a number of railway employees engaged on the systems centering in that city, and according to his report to the State Medical Society, 3½ per cent. of the whole number mistook colors, and 8½ per cent. additional were unable to distinguish accurately the shades of colors. Among those examined were two men who could not distinguish red from green on tests, had educated themselves to know that red was an intense color, and

*English Mechanic, 1879.

thus distinguished bright red signals, but at the same time bright greens and other bright colors were red to them. For these they would stop their trains, and so err on the safe side. On the other hand, dark reds, dark greens, and browns were all the same to them, thus making those colors useless as signals. Another peculiarity in one case was the ability to distinguish bright red close by, but not at a distance.

"A color correctly recognized as bright red at three feet was invariably called green at ten feet and beyond."

Rules for Enginemen.—The following rules are those adopted and in use on the Pennsylvania railroad, and are substantially those in use by all the railway companies in this country.

Enginemen report to, and receive their instructions from the division superintendent. When in the shops, they are under the direction of the master mechanic, or foreman of the shop.

They will obey the orders of the road foreman of engines, in regard to the working of their engines, and the proper use of fuel, stores, etc.

They must obey the orders of the train master, depot master, or despatcher, in regard to shifting and making up trains.

They are under the orders of the conductor of the train in regard to starting, stopping, speed and general management of the train, shifting cars, etc., but they will not obey any order that may endanger the safety of the trade, or require violation of rules.

They must have their engines in good working order, supplied with the necessary stores and tools, fuel and water, and the steam up, ready to attach to the train, at least thirty minutes before the schedule time for starting, and as much earlier as directed by the foremen of the shop, or despatcher.

They must have in their possession a copy of the rules and regulations, the time table, and a full set of signals in good order, and ready for immediate use.

They will be furnished a watch by the division superintendent, and will be held responsible for its safe keeping. They must regulate it by the standard clock of the company, and compare time with the conductor of the train at the commencement of each trip.

They must obey promptly all signals given by station agents,

telegraph operators, track repair men, watchmen, conductors, or trainmen, even though they may think such signals unnecessary. When in doubt as to she meaning of a signal, they must stop and ascertain the cause, and if a wrong signal is shown, they will report the fact to the division superintendent.

They must note that the day and night watchmen are at their posts, and report to the division superintendent any neglect of duty they may observe.

They must use special care in coupling and shifting cars, to avoid injuring the train-men, and must always start and stop their trains cautiously, without sudden jerking.

They must not permit sticks of wood, burning cotton waste, or hot cinders to be thrown from the engine or tender while in motion, and must use every precaution against fire when passing bridges or buildings.

They are not permitted to clean their ash pans on the main track, unless at points specially designated by the division superintendent.

They must not leave their engine during the trip, except in cases of necessity, and must always leave the fireman or some other competent person in charge of it.

They will be provided with checks for wood, coal, oil, and tallow, and they will not be furnished with fuel or stores, unless a check for the correct amount is given the station or storekeeper.

They must report the condition of their engine to the master-mechanic, or foreman of the shop, at the end of each trip, and will assist when called upon, in making any repairs that may be necessary.

They may be required when not in active service on the road to work in the shops, and will then be subject to shop rules.

Rules for Firemen.—Firemen, when on the road, are under the direction of the engineman. When in the shop, they are under the direction of the master mechanic, or foreman of the shop.

They will obey the orders of the road foreman of engines in regard to the proper use of fuel, and manner of firing.

They must be with their engines at least thirty minutes before

the time of starting, and conform to any directions they may receive from the foreman of shop, or despatcher.

They must supply the engine regularly with fuel and water, at the discretion of the engineman, assist in oiling, and use the tender brake in accordance with his orders and signals.

They will assist in keeping a constant lookout upon the track, and must instantly give the engineman notice of any obstruction they may perceive.

They must make themselves thoroughly familiar with the train rules, particularly those that apply to the protection of the train, and must understand the use of the signals, and be prepared to use them promptly.

They must take charge of the engine should the engineman at any time be absent, and not leave it until his return, nor suffer any person not duly authorized to be upon it.

They will not attempt to run an engine in the absence of the engineman without permission from the division superintendent, unless under some emergency they be directed to do so by the conductor, or some officer in authority.

They must assist in cleaning and polishing their engines after every trip, and in making repairs when required.

They may be required, when not in active service on the road, to work in the shops, and will then be subject to shop rules.

Rules for Road-Foreman of Engines.—Road-foremen of engines report to and receive their orders from the division superintendent.

They will obey all orders of the superintendent of motive power, and must report to him as he may direct.

They are required to ride frequently upon the engines, and give instructions to enginemen and firemen in regard to the proper working and firing of engines, with a view to obtaining the best results in the consumption of fuel and stores.

They will give particular attention to the engines for generating steam, and observe that the regulation pressure is not exceeded, and that the boilers are washed out as often as may be necessary.

They must see that the engines are equipped with signals, tools and every article necessary to their efficient working, and that the injectors, air-pumps, etc., are in good working order.

They will advise the division superintendent of the number of cars to be allowed to each class of engines, and report to him when engineers of through freight trains are not given cars to their full capacity, or when any engine is overloaded.

They will consult and advise frequently with the master mechanic and shop foreman, in regard to the daily condition and requirements of engines running upon their divisions.

They will report to the division superintendent the qualifications of enginemen and firemen, and any violation of rules or neglect of duty which may come to their knowledge, and keep him advised of all matters relating to the economical and efficient working of the engines and their crews.

Signals.—There is no established code of signals in use by the railroads of the United States; the following are those of the Pennsylvania Railroad, and are in general those employed by other roads:

Red signifies danger, and is a signal to stop.

Green signifies caution, and is a signal to go slowly.

White signifies safety, and is a signal to go on.

Green and white is a signal to be used to stop trains at flag-stations.

Blue is a signal to be used by car inspectors.

Flags of the proper color must be used by day, and lamps of the proper color must be used at night, or in foggy weather. Red flags or red lanterns must never be used as caution signals, they always signify danger—stop.

A lantern swung across the track, a flag, hat, or any object waved violently by any person on the track, signifies danger, and is a signal to stop.

An exploding cap or torpedo clamped to the top of the rail, is an extra danger signal, to be used in addition to the regular signals, at night, in foggy weather, and in cases of accident or emergency, when other signals cannot be distinctly seen or relied upon. The explosion of one of these signals is a warning to stop the train immediately; the explosion of two of these signals is a warning to check the speed of the train immediately and look out for the regular danger signal.

A fusee is an extra caution signal, to be lighted and thrown on the track at frequent intervals, by the flagmen of passenger trains at night. whenever the train is not making schedule speed between telegraph stations.

A train finding a fusee burning upon the track must come to a full stop, and not proceed until it is burned out.

Engineman's Signals.—By signals. One *short* blast of the whistle is a signal to apply the brakes—stop. (Thus --).

Two *long* blasts of the whistle is a signal to throw off the brakes. (Thus — —).

Two *short* blasts of the whistle when running, is an answer to signal of conductor to stop at next station. (Thus - -).

Three *short* blasts of the whistle when standing, is a signal that the engine or train will back (Thus - - -).

Three *short* blasts of the whistle when running, is a signal to be given by passenger trains, when carrying signals for a following train, to call the attention of trains they pass, to the signals. (Thus - - -).

Four *long* blasts of the whistle is a signal to call in the flagman or signalman· (Thus — — — —).

Four *short* blasts of the whistle is the engineman's call for signals. (Thus - - - -).

Two *long* followed by two *short* blasts of a whistle when running, is a signal for approaching a road crossing at grade. (Thus — — - -).

Five *short* blasts of a whistle, is a signal to the flagman to go back and protect the rear of the train. (Thus - - - - -).

A succession of *short* blasts of the whistle is an alarm for cattle, and calls attention of trainmen to danger ahead.

A blast of the whistle of five seconds duration, is a signal for approaching stations, railroad crossings, and drawbridges.

Conductors' Signals.—By bell cord. A signal bell is placed over-head inside the engine cab, a cord is attached to this bell and passes through to the rear platform of the train.

One tap of the signal bell when the engine is standing, is a notice to start.

Two taps of the signal bell when the engine is standing, is a notice to call in the flagman.

Two taps of the signal bell when the engine is running, is a notice to stop at once.

Three taps of the signal bell when the engine is standing, is a notice to back the train.

Three taps of the signal bell when the engine is running, is a notice to stop at the next station.

Signals by Lamp:—

A lamp swung across the track, is a signal to stop.

A lamp raised and lowered vertically, is a signal to move ahead.

A lamp swung in a circle, is a signal to move back.

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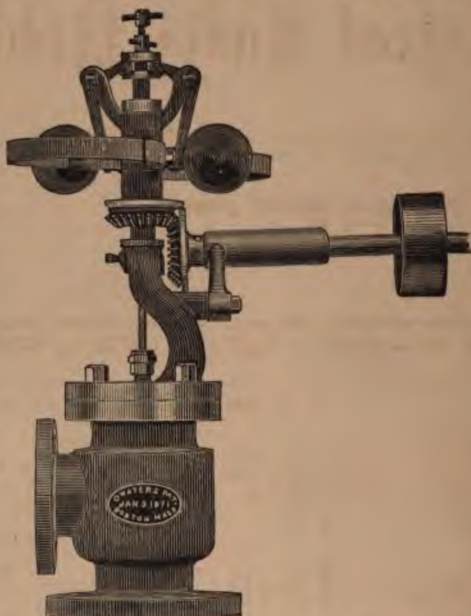

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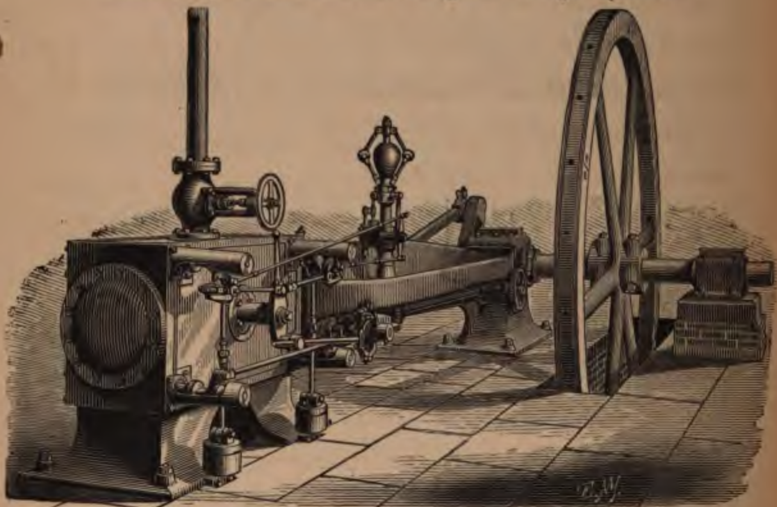

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